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# TREATABILITY OF NINTH AVENUE SUPERFUND SITE GROUNDWATER

by

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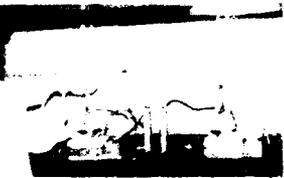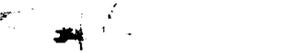
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13. ABSTRACT (Maximum 200 words)

The Ninth Avenue Superfund Site is located in Gary, IN, and has been listed on the US Environmental Protection Agency's National Priorities List since 1973. The site is a 17-acre (68,800-sq m) inactive chemical disposal area within a relatively undeveloped, low-lying area. Past disposal activities resulted in the contamination of the underlying groundwater, predominantly with ketones, benzenes, phenols, and chlorinated aliphatic compounds.

Four technologies were evaluated on the bench scale for their ability to remove organic contaminants from a composite of groundwater samples collected from six site observation wells. These technologies were activated sludge (aerobic biotreatment), activated sludge with powdered activated carbon (PAC) addition, air stripping, and activated carbon.

The results indicate that activated carbon does not have a high sorptive capacity for the site contaminants. Air stripping did not exhibit a high potential for efficiently removing the contaminants from the composite sample.

(Continued)

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However, activated sludge indicated potential for removing the site contaminants. The addition of PAC improved contaminant removal. Increased removals of chemical oxygen demand and total organic carbon from the composite sample with increased PAC dose were observed. Activated sludge and PAC/activated carbon were capable of removing all priority pollutants to concentrations at or below detection limits.

PREFACE

This study was conducted by the US Army Engineer Waterways Experiment Station (WES) as part of the Superfund Feasibility Study of the Ninth Avenue Dump Site. The work was conducted in cooperation with the US Army Engineer District, Omaha, and Region V of the US Environmental Protection Agency (USEPA). Coordination and management support was provided by the Omaha District. Omaha District project manager was Mr. Steve Rowe. Project manager for the USEPA was Ms. Allison Hiltner. Mr. Mark E. Zappi served as WES project manager.

The study was conducted and the report prepared by Messrs. Mark E. Zappi and Norman R. Francingues and Mses. Cynthia Teeter and Elizabeth Fleming of the Water Supply and Waste Treatment Group (WSWTG), Environmental Engineering Division (EED), Environmental Laboratory (EL), WES. The Analytical Laboratory Group, EED, under the supervision of Ms. Ann Strong, assisted with the chemical analysis of samples. Warzyn Engineering, Inc., of Madison, WI, under contract to the Omaha District, obtained the groundwater samples and provided reviews of the technical plan. Messrs. Sidney Ragsdale and Gregory Phillips and Mses. Kellie Huff and Amy Dykes assisted in the design and daily operations of the various bench treatment systems. This report was edited by Ms. Jessica S. Ruff of the WES Information Technology Laboratory.

The study was conducted under the general supervision of Mr. Norman R. Francingues, Jr., Chief, WSWTG; Dr. Raymond L. Montgomery, Chief, EED; and Dr. John Harrison, Chief, EL.

COL Larry B. Fulton, EN, was Commander and Director of WES. Dr. Robert W. Whalin was Technical Director.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Multiply	By	To Obtain
acres	4,046.873	square metres
atmospheres (standard)	101.325	kilopascals
feet	0.3048	metres
gallons (US liquid)	3.785412	cubic decimetres
inches	2.54	centimetres
pounds (mass)	0.4535924	kilograms

TREATABILITY OF NINTH AVENUE SUPERFUND SITE GROUNDWATER

PART I: INTRODUCTION

Site History

1. The Ninth Avenue Dump Site is listed on the US Environmental Protection Agency's (USEPA) National Priorities List of hazardous waste sites scheduled for cleanup under the Comprehensive Environmental Response, Compensation, and Liability Act of 1986, as amended by the Superfund Amendments and Reauthorization Act of 1989. The site is a 17-acre* inactive chemical waste disposal area located in Gary, IN. Figure 1 illustrates the approximate location of the site.

2. The site is situated in an industrial area, although the properties adjacent to the site are relatively undeveloped. The site topography is a relatively flat area with poor drainage and is characterized by small depressions and mounds from past disposal and/or cleanup activities.

3. Both solid and liquid wastes are reported to have been disposed onsite. Solid wastes include industrial construction and demolition wastes. Liquid wastes include oils, paint solvents and sludges, resins, acids, and other chemical wastes. Waste disposal operations took place between 1973 and 1980.

4. Warzyn Engineering, Inc., of Madison, WI, working under contract to the US Army Engineer District, Omaha, performed the remedial investigation (RI) and the remedial action feasibility study (FS). The RI concluded that significant contamination of the site had occurred from past disposal operations. The site groundwater is contaminated with a variety of inorganic and organic contaminants. Inorganic contamination is mainly in the form of sodium chloride (road salts). The suspected source of this contamination is a State of Indiana Highway Department salt storage area located nearby. Other inorganic contaminants found in the groundwater are calcium, magnesium, iron, and potassium. A variety of organic compounds were also detected in the groundwater during the RI. The most prevalent of the organic compounds

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 4.

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detected were ketones. Also detected in significant concentrations were benzene, ethylbenzene, toluene, and xylene (BETX); polynuclear aromatic hydrocarbons (PAHs), and chlorinated solvents. During the RI, a 6-ft layer of waste oil was also detected floating on the groundwater.

5. To eliminate the continual migration of contaminants via groundwater transport and to facilitate site cleanup, a soil-bentonite (SB) slurry wall has been proposed in the RI/FS as a means of containment (Warzyn Engineering, Inc. 1988). The US Army Engineer Waterways Experiment Station (WES) performed a compatibility study between the contaminated groundwater from several site observation wells and two SB slurry wall backfill mixtures (Zappi, Shafer, and Adrian 1990). The study concluded that the groundwater samples were compatible with both backfill mixtures. The location proposed for the SB slurry wall and a detailed site description are given in the Ninth Avenue Superfund Site RI/FS (Warzyn Engineering, Inc. 1988).

Study Objective

6. The objective of this study was to evaluate, on a laboratory bench scale, the potential of various treatment processes to remove organic contaminants from a composite groundwater sample of six site observation wells. Treatment processes evaluated during this study included activated sludge (biological treatment), activated carbon, air stripping, and activated sludge with powdered activated carbon addition.

Scope of Study

7. The scope of the study included an evaluation of the organic contaminant removal potential of the four individual candidate processes on a laboratory bench scale. Neither the combinations of processes for treatment of the groundwater nor the removal of the inorganic contaminants from the groundwater was evaluated. These topics were not included in the scope of work for this study.

PART II: DESCRIPTION OF TREATMENT PROCESSES

Activated Sludge

8. Activated sludge (AS) is a biological treatment process that uses acclimated bacteria for the aerobic degradation of contaminants. Figure 2 is an illustration of a typical AS treatment system. The term "acclimated" means that the bacteria use the contaminants in the system waste influent as their food source, have become adapted to the treatment environment, produce enzymes required for degradation of contaminant(s), or are capable of surviving in the presence of inhibitory contaminants present in the waste influent.

9. Biological treatment is a destruction technology requiring no ultimate disposal of a hazardous waste (assuming that the waste sludges do not contain chemical intermediates due to incomplete oxidation or adsorbed contaminants). In contrast, activated carbon adsorption and air stripping are not destruction technologies, but are simply phase change technologies that transfer the contaminants from one carrier phase to another (i.e., water to solids or water to air).

10. The population of bacteria in the aeration tank is so great that the air-activated organic biological solids made up of the bacterial colonies are referred to as activated sludge. The activated sludge/wastewater slurry in the aeration tank is commonly referred to as mixed liquor.

11. Contaminants are broken down by means of oxidation and hydrolysis reactions performed by the bacteria under aerobic conditions. The aeration tank contains large populations of bacteria that are kept in suspension by either a mechanical mixer or diffused air dispersed through the wastewater. Diffused air injection is usually the preferred method of agitation because the air is also needed as a source of oxygen for the bacteria.

12. Influent is added to the aeration tank at a rate that is carefully controlled to achieved a specific hydraulic retention time (HRT). The HRT has units of time and theoretically describes the amount of time a particle of influent will remain in the aeration tank. The HRT is mathematically defined below as

$$HRT = \frac{V}{Q} \qquad (1)$$

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where

  HRT = hydraulic retention time, days

   V = aeration tank volume, gal

   Q = influent flowrate, gal/day

  13. As fresh influent is added to the aeration tank, treated water or effluent flows out of the aeration tank and into the clarifier. The clarifier is a sedimentation tank used to separate the activated sludge from the treated water or effluent. To keep a constant population of bacteria in the aeration tank, a proportion of the settled activated sludge is returned to the aeration tank via the sludge return lines. Since the bacteria or biomass is constantly reproducing, some proportion of the return sludge must be wasted (typi ally daily) to keep a constant microbial population in the aeration tank.

  14. Populations of bacteria in the aeration tank are typically measured using mixed liquor suspended solids (MLSS) concentrations or mixed liquor volatile suspended solids (MLVSS) concentrations. MLVSS is a much more precise estimate of bacterial population than MLSS because active bacteria are composed primarily of organic materials that are more closely associated with the volatile fraction of suspended solids.

  15. The amount of sludge that is wasted from the clarifier is dependent upon the desired average age of bacteria in the aeration tank. The average age of the aeration tank bacteria is known as the sludge retention time (SRT). The SRT of an AS system in which sludge is wasted from the aeration tank is calculated by the following equation (Metcalf and Eddy, Inc. 1979):

$$SRT = \frac{(V * X)}{(Q_w * Z)} = \frac{V}{Q_w} \qquad (2)$$

where

  SRT = sludge age, days

   V = aeration tank volume, gal

   X = MLVSS, mg/ℓ

  Q_w = amount of mixed liquor wasted per day, gal/day

   Z = solids concentration in waste sludge, mg/ℓ

  16. The SRT can significantly affect the performance of the AS system. It impacts the settling characteristics of the mixed liquor because aged activated sludges tend to settle better than younger sludges. Degradation rates

of various contaminants can vary with SRT. The food-to-microorganism ratio (F/M), a very important system parameter, can also be controlled by the SRT. The F/M ratio is essentially the organic loading of the system. It is calculated by dividing influent organic carbon concentration (using biochemical oxygen demand (BOD), total organic carbon (TOC), or chemical oxygen demand (COD) as a measure of organic carbon concentration) by the population of bacteria in the aeration (MLVSS) and the HRT.

17. Sludge volume index (SVI) is a dimensionless process-descriptive parameter that quantifies the settling characteristics of the activated sludge. Analytical methods for determining SVI are presented in Part V of this report. Activated sludge systems treating municipal sewage usually have SVI values of approximately 100 (Metcalf and Eddy, Inc. 1979). AS systems treating various types of industrial wastes can have very differing SVI values depending on the contaminants being degraded. In most AS systems, increases in SVI generally indicate increased biological activity. Younger sludges have higher SVI values than older sludges. Dramatic changes in SVI are indicative of an AS system that has been upset by shock loadings, reduced influent strength, or the introduction of a toxin to the system.

18. The AS process is classified in terms of biological treatment system configuration as a suspended-growth system. It derives its name from the fact that active bacteria in the aeration tank are kept in suspension by agitation of the mixed liquor. Another class of biological systems that can be used for treatment of contaminated wastewaters is attached-growth systems. These systems use bacteria that remove organic metabolytes from the aqueous phase while attached to a structural medium. Both systems generally use the same basic biological concepts. Each system has decidedly different advantages and disadvantages associated with it. The suspended-growth system was selected for evaluation because it is easier to acclimate bacterial cultures using small AS reactors and to simulate the full-scale treatment system on the bench scale.

19. Some advantages of suspended-growth systems over attached-growth systems are that they (a) can usually handle larger daily organic loadings, (b) will usually yield lower effluent contaminant levels, and (c) are usually more dependable.

20. Some advantages of attached-growth systems over suspended-growth systems are that they (a) are usually more resistive to shock loadings of highly contaminated influent or influents containing toxins, (b) usually

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require less operator attention, (c) require lower influent contaminant concentrations to support biological activity, and (d) can be configured to eliminate or substantially reduce the off-gassing of volatile contaminants from the biological treatment system (bioreactor).

21.   Some major disadvantages of suspended-growth systems are that they have the potential for generation of contaminated off-gases (volatilization of solutes from the influent) from the aeration tank and are operator intensive. Some disadvantages of the attached-growth systems are that they are susceptible to clogging due to excessive biological growth or oxidized cations and typically produce a lower quality effluent compared with the suspended-growth systems.

Activated Carbon Adsorption

22.   Activated carbon (AC) adsorption is a popular physical treatment process in which solutes (contaminants) in the wastewater are adsorbed onto the surface of the activated carbon. The AC process is used widely in the removal of organic contaminants from a variety of contaminated wastewaters (Faust and Aly 1987). AC adsorption is not a destruction technology, but a phase change technology in which the contaminants are transferred from the aqueous phase onto the solid phase. The attractiveness of AC is that, at equilibrium, the phase transfer results in a concentration of the contaminants from the aqueous phase onto the AC surface.

23.   The adsorption process can actually be both physical and chemical (Faust and Aly 1987). Physical adsorption of the contaminants is attributed to forces of interaction between the solid surface and the contaminant that are similar to Van der Waals forces between molecules. Chemical adsorption or chemisorption occurs when the formation of an actual chemical bond occurs between the AC and the contaminant. Physical adsorption is the most common mechanism for adsorption of contaminants from wastewater onto AC (Metcalf and Eddy, Inc. 1979).

24.   AC treatment is typically implemented by the use of fixed beds of granular activated carbon (GAC) or the addition of powdered activated carbon to a mixing tank. Figure 3 is an illustration of a typical GAC treatment system. Contaminated influent enters the adsorber from the top and exits through the bottom of the adsorber comparatively free of contaminants. The "bed" of AC removes contaminants from the influent until all of the available

AC sorption sites are occupied. Once all of the adsorption sites are occupied, the bed of AC is considered "spent" and requires replacement with fresh AC.

25. When AC systems are used to treat contaminated influents containing multiple contaminants with varying adsorptive characteristics, a phenomenon known as competitive adsorption can occur when all of the sorption sites have become occupied by the sorbed contaminants. During competitive adsorption, contaminants that are more strongly adsorbed on AC outcompete the weaker adsorbed contaminants for the available sorption sites of the AC by actually displacing the weaker adsorbed contaminants from the AC adsorption site. In some cases of multicomponent influent treatment, effluent contaminant concentrations of some contaminants can be greater than the respective influent concentrations due to competitive adsorption occurring between the various contaminants in the influent for the filled AC adsorption sites (Zappi et al. 1990).

26. The controlling factor for AC treatment systems is the adsorption capacity of the AC for the contaminants. Different types of AC are available which vary by the type of parent material used to manufacture the AC and adsorptive capacity for different contaminants.

27. Adsorption capacity for different contaminants can vary with AC type and brand (Faust and Aly 1987). The theoretical maximum equilibrium adsorption capacity (X/M) of a particular AC for a contaminant is essentially fixed, although changes in pH and inorganic species concentrations can slightly change this capacity (James Montgomery Engineers, Inc. 1985). However, the hydrodynamics of most adsorption systems typically do not allow for full chemical adsorption capacity of the AC bed to be reached.

28. One operational and/or design factor that can be used to increase the efficiency of an AC system is empty bed contact time (McGuire and Suffet 1980). Empty bed contact time (EBCT) is the HRT of the water based on total volume of the adsorber with no AC present. Usually, higher EBCTs result in higher system adsorption capacities. Since higher EBCTs require more adsorber volume to treat an equivalent amount of water treated at a lower EBCT, the EBCT must be optimized in terms of influent flow rate, required contaminant removal efficiency, and adsorber volume.

Air Stripping

29. Air stripping is a physical treatment process that does not result in the destruction of the contaminants, but simply relies on contaminant phase change. Air stripping removes contaminants via volatilization from the aqueous phase into the gas phase. It is apparent that compounds that are amenable to treatment using air stripping technology are those that are volatile. The higher the Henry's law constant of the contaminant, the easier it is to desorb or "strip" the contaminant into the vapor phase. For air stripping to be cost effective, the contaminant(s) of interest must be significantly more volatile than water.

30. Figure 4 is an illustration of a typical air stripping system. Influent flows downward through a packed distillation column while air is blown up countercurrent to the water flow through the column. The packing provides a high surface area for contaminant desorption (i.e., phase change) to take place.

31. The contaminant removal efficiency of an air stripping unit can be controlled using several process controls. One such control is the ratio of air flow to water flow into the unit. Increased air-to-water ratios will usually result in decreased effluent concentrations; however, there is a limit to the benefits of increasing the air-to-water ratio to decrease the effluent concentrations (Hand et al. 1986).

32. Increasing temperature will increase the Henry's law constant of the contaminant, and thereby the contaminant removal efficiency of the air stripper. Temperature increases may be accomplished by increasing the temperature of the air and/or water entering the system. Increased column height and packing surface area will also result in an increase in contaminant removal efficiency of an air stripping unit.

Powdered Activated Carbon/Activated Sludge

33. Powdered activated carbon/activated sludge (PAC/AS) is a treatment process that incorporates both AC and AS for the removal of organic contaminants from wastewater. PAC/AS treatment is typically used for wastewaters containing both refractory and biodegradable compounds.

34. The PAC/AS treatment process relies heavily on biological degradation for the removal of most of the contaminants from the wastewater. The PAC

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adsorbs nonbiodegradable (referred to as refractory or recalcitrant) compounds and/or the relatively difficult to degrade compounds from solution that the bacteria cannot immediately oxidize, due to the presence of easier to degrade compounds, until the bacteria are able to later degrade the more difficult to degrade compounds from the surface of the PAC. PAC addition is also used as a means of reducing the release of volatile organic compounds from an AS aeration tank by the adsorption of these compounds onto the PAC. Once adsorbed, the volatile compounds can be degraded from the surface of the PAC by the bacteria.

PART III: LITERATURE REVIEW OF TREATABILITY OF
CONTAMINANTS BY PROCESS

Activated Sludge

35. The suitability of AS for the degradation of a variety of complex
organic contaminants has been demonstrated by many researchers (Kim, Humenick,
and Armstrong 1981; Venkataramani and Ahlert 1984; Kelly 1987). Most of the
research activities reviewed generally used the same technical approach to
evaluate biological treatment that was used in this study.

36. Sanford and Smallbeck (1987) used a mixed culture of bacteria and
yeast to degrade a synthetic wastewater comprised of 100 ppm acetone, 50 ppm
methyl ethyl ketone (2-butanone), and 125 ppm methyl isobutyl ketone in bench-
scale chemostats. They concluded that treatment of ketones was successful
within 48 hr of batch treatment using a stable culture of microorganisms and
yeast.

37. Kim and Maier (1986) evaluated the acclimation and biodegradation
potential of chlorinated organic compounds in the presence of co-metabolytes.
They were able to acclimate a culture of bacteria from a municipal AS plant
capable of degrading 2,4-D (2,4 dichlorophenoxyacetic acid) and 3,5-DCB (3,5
dichlorobenzoate) under aerobic conditions. Combined contaminant concentra-
tions as high as 100 mg/ℓ were successfully degraded. They concluded that
seed bacterial consortiums should contain as diverse a population of micro-
organisms as possible to increase the probability of plasmid exchange and that
the acclimation phase should begin with an influent containing very low con-
centrations of the target compounds to avoid inhibitory effects.

38. Bieszkiewicz and Pieniadz-Urbaniak (1984) evaluated the effects of
benzene and xylene at concentrations as high as 75 and 150 mg/ℓ, respectively,
on the work of an AS system. They concluded that increased concentrations of
the target compounds generally decreased COD removals, increased SVI,
increased the number of free-swimming bacteria, and altered the morphology of
the bacterial flocs.

39. Rozich and Gaudy (1985) evaluated the response of an AS system to
quantitative shock loadings of phenol. A phenol concentration of 500 mg/ℓ was
evaluated as a base influent concentration. Initially, shock loadings of
1,000 mg/ℓ of phenol were imposed on the AS system without significant distur-
bances in treatment occurring. The AS system was then shocked with 2,000 mg/ℓ

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of phenol, which resulted in a collapse of the stability of the AS system. The investigators concluded that design engineers should design AS systems that will be treating possible inhibitory and/or toxic compounds with high design SRTs (especially those systems that could be subjected to periodic shock loadings of contaminants).

Activated Carbon

40. The successful treatment of a variety of organic contaminated wastewaters using AC has been demonstrated by a variety of case studies (Faust and Aly 1987). Design methodologies of AC treatment units are well documented (Faust and Aly 1987; Metcalf and Eddy, Inc. 1979; James Montgomery Engineers, Inc. 1985).

41. Little research into the adsorptive capacity of AC for ketones was found. However, a vast amount of information is available on the adsorption of phenols and BETX compounds by AC (Faust and Aly 1987). These studies generally indicate that the heavier molecular weight compounds are much easier to adsorb then the lighter weight organics. Morton, Card, and Byers (1984) summarized their experience with AC systems in that compounds with Freundlich k coefficients lower than 7.0 mg/g are generally difficult to adsorb.

42. Stenzel and Rabosky (1986) concluded that adsorbability increases with increased molecular weight, decreased solubility, and the increased presence of chlorine substitution and aromatic structures. They also concluded that removal of 1,1 dichoroethane with an AC, having an AC adsorbability of 5.0 mg/g, could economically be achieved.

43. O'Brien and Fisher (1986) reported appreciable removals of acetone, BETX, phenol, methylene chloride, and a variety of organic compounds. They estimate AC usages of <1.01 lb/1,000 gal of water treated for a wastewater containing BETX concentrations of 28 mg/ℓ and 5.8 lb/1,000 gal of treated water initially containing phenol and orthochlorophenol at concentrations of 63 and 100 mg/ℓ, respectively (AC usage rates for acetone removal were not presented).

Air Stripping

44. Very little information was available on the air stripping potential of the contaminants present in the Ninth Avenue Site groundwater.

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Morton, Card, and Byers (1984), based on their experience, concluded that compounds with Henry's law constants less than 10.0 atm are generally very difficult to strip. They list phenol as having a Henry's law constant of 0.07 atm. BETX compounds are listed by Morton, Card, and Byers (1984) as having Henry's law constants in excess of 300 atm.

45. Several design methodologies for air stripping have been proposed, with little or no difference in the overall technical approach (Lenzo 1985; James Montgomery Engineers, Inc. 1985; Roberts et al. 1985; Nirmalakhandan, Lee, and Speece 1988). Speece, Nirmalakhandan, and Lee (1987) developed nomographs for air stripping design. Chao, Liu, and Rasdorf (1988) developed a microcomputer spreadsheet design program for air stripping units.

46. Hand et al. (1986) evaluated the effect of varying air-to-water ratios and tower volumes on trichloroethylene removal efficiencies. They observed that, as influent concentrations are increased, the air-to-water ratios can be increased to maintain the required contaminant removal rate. They also observed during the full-scale implementation of an air stripping unit that significant amounts of oxidized iron and manganese were found in the tower packing. The influent iron and manganese concentrations were 1.5 and 2.5 mg/ℓ, respectively. They concluded that the cations must be removed from the influent, or the precipitated cations would pose serious operational problems, and that there was an optimal design that achieved high trichloroethylene removal rates yet required minimal tower volume due to the use of increased air-to-water ratios (>100).

47. Sullivan, Lenzo, and Johnson (1985) evaluated the potential for air stripping to remove 2-butanone at concentrations of 1,000 mg/ℓ. They found that air stripping alone would remove only 25 percent of influent 2-butanone. However, they concluded that preheating the influent and column to temperatures in excess of 60° C and providing air-to-water ratios of 200:1 would remove approximately 99.9 percent of the methyl ethyl ketone from the influent.

PAC/Activated Sludge

48. Considerable research has been done on the feasibility of applying PAC/AS to treat a wide variety of wastewaters (Copa and Meidel 1986; Dietrich et al. 1988). Nayar and Sylvester (1979) evaluated PAC addition to an AS system for increased removal of phenol. Concentrations of phenol as high as

1,300 mg/ℓ were successfully removed. Nayar and Sylvester (1979) concluded that the addition of PAC to the aeration chamber did not seem to enhance bacterial growth; however, PAC addition could be used to prevent shock loadings of contaminants at toxic concentrations from adversely disrupting the bacterial consortium.

49. Chao, Yeh, and Shieh (1986) evaluated the use of PAC/AS systems to remove total phenols and cyanides at concentrations as high as 160 mg/ℓ and 80 mg/ℓ, respectively. They concluded that the PAC addition did not have an appreciable effect on phenol removal. However, they did observe increased cyanide removals with PAC addition.

50. Hoffman and Oettinger (1987) investigated the performance of a two-stage PAC/AS and AC system for the removal of trichloroethylene, 1,4-dichlorobenzene, and 2-chlorophenol at a combined concentration of 101.9 mg/ℓ from a landfill leachate. They concluded that 99.8-percent removal of the contaminants could be achieved using the two-stage system, with only 0.31 percent of the contaminants being removed due to air stripping in the aeration tank of the AS system.

PART IV: TECHNICAL APPROACH

51. The extent of each process evaluation was limited to the practical-
ity of evaluating the technology on the bench scale. Therefore, the biologi-
cal treatment and the biological treatment with PAC addition were evaluated
more extensively than air stripping and activated carbon due to the practical
limitations of performing bench-scale evaluations of the latter treatment
systems.

52. Two influents were used throughout the course of this study. These
influent samples were a composite of groundwater samples collected from six
site observation wells. The composite samples contained contaminants at
levels considered to represent the maximum influent concentrations the pro-
posed treatment system would have to treat. The technical steps used to eval-
uate each of the treatment processes evaluated are outlined below.

Activated Sludge

53. Steps in the procedure used to evaluate the AS process were as
follows:

- Acclimate a culture of bacteria for degradation of the contami-
  nants in the site groundwater.

- Determine the contaminant removal efficiency of the AS system
  using the acclimated consortium.

- Assess the benefits of the addition of a commercially available
  bacteria for improved removal of the gross and priority pollut-
  ants from the groundwater composite.

- Determine optimal AS treatment conditions and design coeffi-
  cients using multiple bioreactors (chemostats).

- Reduce data and make evaluations.

Activated Carbon

54. Steps in the procedure used to evaluate the AC process were as
follows:

- Select an activated carbon source (i.e., brand).

- Determine the adsorption equilibrium time of the groundwater
  contaminants and the AC for equilibrium batch testing.

- Perform adsorption equilibrium batch testing under zero head conditions to eliminate or substantially reduce volatile compound losses during agitation of the AC/water slurries.

- Develop adsorption isotherms and make evaluations.

Air Stripping

56. Steps in the procedure used to evalute the air stripping process were as follows:

- Determine the required amount of time for all of the contaminants that can be air stripped to be removed from solution (i.e., equilibrium time).

- Perform air stripping runs using bench scale air stripping units.

- Develop air stripping desorption plots and make evaluations.

PAC/Activated Sludge

57. Steps in the procedure used to evaluate the PAC/AS process were as follows:

- Composite the MLSS from the four AS bioreactors into the large bioreactor to ensure that the same microbial population is used in four PAC bioreactors.

- Select a SRT for all of the PAC bioreactors based on the results of the activated sludge study.

- Select PAC source.

- Add PAC doses of 1,000, 2,000, 5,000, and 8,000 mg/ℓ into four bioreactors.

- Reduce data and make evaluations.

PART V: MATERIALS AND METHODS

Materials

Groundwater samples

57. Test influents used in this study were two separate yet similar composite samples of groundwater collected from six site observation wells. The first influent was a composite sample (Composite No. 1) prepared by combining equal proportions of groundwater from site observation well Nos. X-4, X-5, X-15, X-20, X-22, and X-25. These groundwater samples were collected on 12 December 1989 by Warzyn Engineering, Inc., personnel. A total of 245 gal was collected and shipped to WES in 5.0-gal steel pails by SET Environmental Transporters, Inc., of Chicago, IL. The pails were completely filled with the groundwater sample, and tightly capped to minimize the loss of volatile compounds during shipment of the samples to the WES.

58. Upon receipt, the samples were stored in a walk-in cooler at 4° C under a WES chain-of-custody. The acclimation phase of the biological treatment evaluations and the adsorption batch equilibrium time determination tests of the activated carbon evaluations used Composite No. 1.

59. A slightly different groundwater composite sample (Composite No. 2) was used as test influent for various phases of the study because one of the original site groundwater wells (X-15) sampled during the first sampling effort had no groundwater during the second sampling effort. Therefore, groundwater samples from observation well X-15 were replaced with groundwater from well X-14. The decision to use X-14 in place of X-15 was made because X-14's water chemistry was found to be very similar to that of X-15's based on a review of the analytical data collected during the RI (Warzyn Engineering, Inc. 1988).

60. The groundwater samples for the second composite were also collected by Warzyn Engineering, Inc., personnel. A total of 555 gal of groundwater samples were received by WES on 13 July 1989 in 5.0-gal plastic jugs with zero headspace. The samples were shipped by SET Transporters, Inc., and stored in the walk-in cooler at 4° C under a WES chain-of-custody.

61. Composite No. 2 consisted of samples from wells X-4, X-5, X-14, X-20, X-22, and X-25. The amount of sample taken from each of the wells and shipped to WES varied depending on the availability of groundwater in each

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well during the sampling effort. To ensure that enough Composite No. 2 sample would be available to complece all remaining phases of the treatability study, a proportional amount of sample from each well (based on the amount of ground-water samples shipped) was used to formulate Composite No. 2. The following portions of sample from each well were used to prepare Composite No. 2: well X-5, 31 percent; wells X-22 and X-25, 15 percent each; wells X-4 and X-20, 14 percent each; and well X-14, 11 percent. The results of the chemical analysis of both ground-water composites are presented in the Part VI of this report.

Bioreactors

62. The bioreactors used during the treatability studies, including the bioreactor used during the acclimation phase, were designed and constructed at WES. The design of the bioreactors (illustrated in Figure 5) incorporated the aeration and clarifier in one unit with a common wall separating them. This design minimizes the amount of tubing and pumps required to operate the system, yet allows the settled sludge to return to the aeration chamber without the use of a pump. (Bench-scale AS systems with separate aeration tanks and clarifiers tend to experience problems with the clarifier sludge return tubing clogging due to excessive biological growth in the tubes.) Sludge wasting was accomplished through the sludge waste port located on the side of the aeration chamber (Figure 5). After allowing the waste sludge to settle, the supernate was returned to the aeration chamber to make up for the water lost during the wasting of the mixed liquor from the aeration chamber.

63. The acclimation phase of the biological studies used a bioreactor with a 15.0-ℓ aeration chamber and a 5.0-ℓ clarifier. The multiple-reactor phase or AS study phase used bioreactors with 2.0-ℓ aeration chambers and 1.0-ℓ clarifiers. The aeration chamber-to-clarifier volume ratio of the small bioreactors was increased to 2:1, as compared to the 3:1 ratio used in the acclimation study. This was done as an attempt to improve the settling efficiencies of the small bioreactor clarifiers by reducing the surface overflow rate. Poor settling of the mixed liquor in the large bioreactor's clarifier was observed during the acclimation study.

64. Cole-Palmer peristaltic positive displacement pumps were used to feed influent into the bioreactors. The tubing used during the acclimation and biological treatment phases was Cole-Palmer silicon tubing Nos. 14 and 24, respectively.

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65. Dissolved oxygen (DO) concentrations in the bioreactors and BOD bottles were measured using a Yellow Springs model 57 meter. Yellow Springs DO probe model Nos. 31 and 5720A were used to measure DO in the bioreactors and BOD bottles, respectively.

66. Organic volatile compound concentrations in the off-gases from the reactors were measured using a HNU organic vapor analyzer. Reactor temperatures were measured using Fisher laboratory-grade thermometers. Salinity and conductivity measurements were made using a Yellow Springs model 33 S-C-T conductivity and salinity meter and probe.

Bacterial cultures

67. The bacterial cultures used to initiate the acclimation phase of biological testing were collected from the city of Jackson, MS, wastewater treatment plant. These culture samples were collected in 5.0-gal buckets by WES personnel during December 1989, from the aeration tank of the Jackson system, which is a publicly owned treatment works (POTW). The Jackson POTW is a contact stabilization system. The feed influent wastewater used initially in the acclimation phase was collected from the influent sump for the trickling filters of the wastewater treatment plant located in Vicksburg, MS.

68. During the acclimation phase, a commercially available specialty bacterial culture marketed as Super Cee by Microbe Masters, Inc., of Denham Springs, LA, was added to the acclimation reactor in an attempt to increase the removal of COD and TOC from the influent. This culture, according to Microbe Masters, was especially acclimated for many of the contaminants found in the site groundwater.

Activated carbon

69. Activated carbon used in both the AC and PAC/AS studies was received from the Calgon Carbon Corporation, Pittsburgh, PA. Carbon type BL was selected in consultation with Calgon, based on the characteristics of the site groundwater composites used as test influents. Carbon type BL is available in both the granular and powdered form. The PAC form was used in both the isotherm equilibrium batch AC study and the PAC/AS study because both test methods require the use of pulverized AC samples. The AC/groundwater composite slurries were agitated using a rotary-type laboratory tumbler similar to the one illustrated in Figure 6.

Bench-scale air strippers

70. The bench-scale air stripping units that were used are illustrated in Figure 7. This system was based on one of similar design proposed by

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Thibodeaux (1974). The air stripping units (made of glass) were constructed for WES by Kontes Glass, Inc., Vineland, NJ. Fisher 6-mm Teflon raschig rings were used as column packing. Cole-Palmer peristaltic pumps and tubing size No. 14 were used to recirculate the water throughout the air stripping unit. Air flow into the units was controlled using Cole-Palmer air flowmeter/ regulators. The HNU meter was used to measure VOC concentrations in the off-gases from the units.

Experimental Methods

Preparation of groundwater composites

71. Groundwater samples used to formulate Composite Nos. 1 and 2 were composited daily to minimize VOC losses. A specialized mixing protocol was developed to minimize VOC losses. This mixing protocol is summarized in the following paragraphs.

72. Mixing operations were performed using a peristaltic pump with silicon tubing. (Peristaltic pumps were used because they allowed transport of the samples without exposure to air.) The suction end of the tubing was inserted all the way to the bottom of each groundwater sample container, and the required amount of sample was pumped into a 5,000-ml graduated cylinder with the discharge end of the tubing submerged in the sample contained in the graduated cylinder.

73. All six groundwater samples were pumped into the same graduated cylinder. The contents of the graduated cylinder were not emptied until all six samples had been pumped into the cylinder. As the cylinder was filling, the discharge end of the tubing was moved up and down to facilitate sample mixing. Once the required amounts of each respective samples were added to the graduated cylinder, the composite sample was pumped out of the cylinder using the peristaltic pump and into the influent reservoir of the bioreactors. The influent reservoir was sealed with a lid that had sufficient openings for each bioreactor's influent feed lines.

Bacterial culture acclimation

74. The acclimation bioreactor was completely filled (including the clarifier section) with the mixed liquor from the Jackson wastewater treatment system. Acclimation of the bacterial consortium to the contaminants in the groundwater was based on the acclimation system receiving a constant organic loading throughout the acclimation phase. Influent from the Vicksburg POTW

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was used as the initial feed into the acclimation bioreactor. Table 1 lists the feed proportions of Vicksburg POTW wastewater and Ninth Avenue groundwater composite over the 23-day acclimation period. These proportions increased until the bioreactor influent was comprised only of site groundwater.

75. The acclimation bioreactor was operated at a SRT of 10 days and a variable HRT. The HRT used was dependent on the influent BOD concentration, such that the system organic loading remained constant throughout the acclimation of the bacterial culture. The wastewater from the Vicksburg POTW had a BOD of approximately 70 mg/ℓ; therefore, glucose was added to increase the influent BOD to approximately 200 mg/ℓ to achieve a constant organic loading of 0.01 lb BOD/day on the system. This organic loading was the equivalent of the organic loading the reactor would experience using the groundwater composite as the system influent with a HRT of 3 days and an estimated groundwater composite BOD of 800 mg/ℓ (Warzyn Engineering, Inc. 1988). Upon completion of the acclimation phase, the bioreactor was operated at a HRT of 3 days.

76. Composite No. 1 was used as bioreactor influent during the acclimation phase. Composite No. 1 had approximately 73.2 mg/ℓ of ammonia as nitrogen, which was considered high enough to prevent the bioreactor from becoming nitrogen nutrient limited. The Composite No. 1 orthophosphate concentration was only 0.601 mg/ℓ and was insufficient to provide the phosphorus needed for the biological processes. Therefore, Composite No. 1 was supplemented with approximately 10 mg/ℓ of total phosphate by the addition of potassium monobasic and dibasic phosphate to the influent. Composite No. 2, used in the other phases of biological testing, had the same phosphorus concentrations; therefore, the same amount of the phosphorus compounds was added to the influent. Effluents from all phases of biological testing had ammonia and orthophosphate concentrations in excess of at least 15.0 and 2.0 mg/ℓ, respectively. These concentrations ensured that none of the bioreactors was either nitrogen or phosphorus limited.

77. The rate at which the proportion of groundwater to POTW influent was increased was determined before testing began under the assumption that the bacterial consortium would easily acclimate to the groundwater composite, with little or no lag phase, when maintained under a constant system organic carbon loading. Therefore, during the transitional period when groundwater was replacing the POTW influent, changes in gross contaminant removals (TOC, COD, and BOD are classed as gross pollutants) and the VSS/SS ratio were

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monitored. This was done to ensure that the contaminants in the groundwater were not detrimental to the bacterial consortium. If adverse effects were detected, these could be reversed or minimized by decreasing the rate of addition of groundwater to POTW comprising the system influent.

78. Once the system influent consisted of only Composite No. 1 and the percent removal of BOD and the VSS/SS ratio were constant, the bacterial culture was considered acclimated.

79. A chemical analysis for gross and priority pollutants of the effluent was performed prior to the addition of the commercial bacteria (Super Cee). Addition of a commercially available culture was performed to determine if these microorganisms would improve the quality of the acclimation bioreactor's effluent. The culture was added according to the instructions supplied by the commercial seed vender, Microbe Masters. These instructions are presented as Appendix A to the report.

80. A number of samples were collected to assess the acclimation of the bacteria and to evaluate the percent removal of gross and priority pollutants. The sampling matrix used for all phases of the biological study is summarized in Table 2, which lists sample type, analyte, and sampling frequency. Included in the acclimation sampling effort was an analysis of effluents collected on 2 test days to determine the percent removal of priority pollutants. The analytical detection limits used were those requested by the USEPA and were lower than those normally used for priority pollutant analyses.

Activated sludge

81. After the acclimation phase was considered complete, the mixed liquor from the acclimation bioreactor was added to four of the small bioreactors. Approximately 3.0 ℓ of mixed liquor was added to each bioreactor. This amount of mixed liquor completely filled the aeration chambers and clarifiers of the four small bioreactors.

82. Each AS bioreactor was operated at a HRT of 1.0 day. The bioreactors differed from each other by SRTs of 2, 4, 8, and 16 days. The purpose of varying the SRTs was to determine an optimal SRT and to calculate various biokinetic constants using graphical approximation methods discussed in Part VI.

83. The influent composite sample used in the AS phase was Composite No. 2. The same amount of phosphate nutrient that was added to Composite No. 1 was added to Composite No. 2. Because of delays in receiving the second groundwater sample shipment, the four bioreactors were initially fed

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groundwater composite No. 1. While awaiting the arrival of the second groundwater shipment, WES began to run out of groundwater samples from various wells until the influent eventually consisted only of groundwater from well X-20. This period of interim AS bioreactor operations was designated the transitional phase.

84. To conserve valuable groundwater sample, the HRT for each bioreactor was increased to 2.0 days. During the transitional phase, the bioreactors were monitored for influent and effluent BOD, VSS, SS, and the operating parameters measured daily during the acclimation phase (Table 2). Once the second shipment of groundwater samples had arrived, bioreactor operations were restored to a HRT of 1 day. The bioreactors were allowed to equilibrate for approximately 3 weeks before AS testing was officially started. During this period the bioreactors were observed closely to ensure that Composite No. 2 was not adversely affecting the performance of the bioreactors.

85. A fifth reactor, identical to the other four bioreactors, was operated without the addition of biomass to evaluate the amount of treatment achieved with aeration only. This reactor was classified as the control reactor.

86. During the course of AS testing, a variety of analyses were performed on the influents and effluents (Table 2). To reduce the amount of VOCs lost during chemical analysis, all influent and effluent samples were analyzed without filtration.

Activated carbon

87. Activated carbon was evaluated by constructing adsorption isotherms from data generated from the equilibrium batch testing of Composite No. 2 and known weight additions of AC. Before actual batch equilibrium testing began, batch chemical equilibrium time was determined. Equilibrium time is the amount of time required for the AC and Composite No. 1 to reach chemical adsorption equilibrium.

88. Adsorption equilibrium testing was performed under zero head conditions in sealed glass 820-ml centrifuge bottles. Zero head conditions were used to prevent loss of VOCs during system agitation. Ten grams of AC was added to 16 centrifuge bottles containing approximately 800 ml of Composite No. 1 and 10 glass beads. The glass beads were added to facilitate mixing while tumbling the samples in the rotary tumbler. The centrifuge bottle caps were all lined with Teflon to prevent adsorption of the contaminants to the

cap liner. The amount of Composite No. 1 and AC sample added to each bottle was recorded, along with the pH and temperature of the groundwater samples.

89. The centrifuge bottles were filled with the AC/groundwater slurry and glass beads, and were tumbled end-over-end on the sample tumbler (Figure 6) until they were removed for phase separation and analysis. Two centrifuge bottles were removed from the tumbler at test times of 0.5, 1.0, 2.0, 4.0, 8.0, 16.0, 48.0, and 96.0 hr and were centrifuged at 1,800 rpm for 30 min before being analyzed for BOD, TOC, COD, salinity, conductivity, and priority pollutant VOCs. Duplicate bottles were used to provide enough sample for all of the analyses. The concentration of each analyte at each test interval was plotted against test time to determine equilibrium time for that contaminant.

90. There was some concern after receiving the results of the equilibrium time testing that the 10 g of AC had reached its maximum adsorptive capacity during testing, because of the short period of time it took the AC to reach equilibrium. Therefore, a second equilibrium time test was performed using an AC·dose of 30 g. Time intervals for this test were 0.25, 0.5, 1.0, 2.0, 4.0, 8.0, and 16.0 hr. The influent and subsequent equilibrium samples were analyzed for TOC. These series of 30-g batch tests indicated that the adsorption equilibrium time determined during the 10-g AC dose runs were equilibrium controlled and not AC loading controlled.

91. Once an equilibrium time was determined, an equilibrium batch test using varying AC dosages was initiated. This test was performed using the same testing procedure as described above except that AC doses of 1.0, 5.0, 20.0, 40.0, and 100.0 g were evaluated. Groundwater Composite No. 2 was used for this phase of AC testing. All of the samples were removed at the predetermined equilibrium time and analyzed along with an influent and operational blank sample fc pH, temperature, TOC, COD, BOD, salinity, conductivity, and priority pollutant VOCs and base neutral-acid extractables (BNAs). The concentration data were used to construct adsorption isotherms.

92. After reviewing the adsorption isotherms, it was apparent that more batch adsorption data points would be useful in development of the TOC and COD isotherms. Therefore, a second equilibrium batch adsorption test was run using additional AC doses of 0.01, 0.05, 0.1, and 0.5 g. These samples were run as previously described and were analyzed for TOC, COD, pH, conductivity, and salinity.

Air stripping

93. The air stripping test was run following the methods described by Thibodeaux (1974). Duplicate air stripping units were used for all test runs, except the COD test run. The first run was performed to determine the amount of time to remove all of the available volatile TOC from the wastewater and to collect TOC air stripping data.

94. Two bench-scale air stripping units for the TOC run were filled with approximately 800 ml of Composite No. 1. An air flow rate of 12,000 ml/min upward through the columns was achieved by adjustment of the air flowmeters. A countercurrent flow of groundwater was controlled at a rate of 150 ml/min using the peristaltic pumps. These flow rates yielded an air-to-water flow ratio of 80:1.

95. System temperature was maintained at 20° C during testing by using the hotplate feature of the combination hotplate and magnetic stirrer, if necessary. Temperature of the water and air was measured by inserting a laboratory-grade thermometer into the glass beads used for water distribution. The water in the flask was kept well mixed by using a Teflon stir bar and the combination magnetic stirrer/hotplate. The total weight of each air stripping apparatus was measured prior to the initiation of air flow through the column.

96. Every 20 min, TOC samples were collected from each unit via the three-way sampling valve (see Figure 7). The amount of sample collected was recorded to complete a water budget around the system (Thibodeaux 1974). At the same time each sample was collected, a measurement of VOCs in the off-gas stream from each unit was taken using the HNU meter. Nine effluent samples and one influent sample were collected and analyzed. At the end of testing, the amount of water evaporated was determined by completing a water balance around the two air stripping units.

97. Based on the TOC runs, it was determined that a test time of approximately 1 hr was adequate to desorb most of the VOCs from Composite No. 1. Subsequent air stripping runs were made analyzing for priority pollutant VOCs and COD using Composite No. 2. The VOC air stripping test runs were performed under the same conditions as the TOC runs, except that the air entering the units was passed through a chamber of desiccation pellets (Drierite brand) to remove water vapor from the air to maximize water loss due to evaporation as described by Thibodeaux (1974). The amount of water lost due to evaporation was quantified by performing a water balance around the two air stripping units.

98. A COD test run was also performed following the same procedures described above, except that duplicate COD runs were not performed. The COD run was also performed using the dehumidified air.

99. The data generated during all of the air stripping runs were evaluated using the methods described by Thibodeaux (1974). A description of the data evaluation method and an explanation of the results are presented in Part VI.

Powdered activated carbon/activated sludge

100. After completing the AS study, the mixed liquors from each of the four bioreactors from the AS study were composited into the large acclimation bioreactor. The compositing was done to ensure that the bacterial cultures used in each PAC/AS bioreactor were initially very similar in terms of population and physiological type (AS systems operated at different SRTs may contain very different bacterial types). The bioreactor was operated at a SRT selected from the AS study and a HRT of 1.0 day. The large bioreactor was operated for a period of three SRTs; then, approximately 10 ℓ of mixed liquor from the aeration chamber was placed into four of the small bioreactors.

101. PAC doses of 1.0, 2.0, 5.0, and 8.0 g/ℓ were added to PAC/AS bioreactor Nos. 1 through 4, respectively. The amount of PAC removed each day in the waste sludge was replaced with equal amounts of fresh PAC after sludge wasting operations were completed. New PAC was placed into the PAC/AS bioreactors by slurrying the PAC with enough bioreactor effluent to make up for the volume of water lost from the sludge wasting activities.

Analytical and Sampling Methods

102. The analytical and sampling methods used during this study are described below. The quality assurance/quality control procedures used during this study can be found in "Quality Assurance for Environmental Chemical Analysis" (Strong 1990).

Suspended and volatile solids

103. Suspended and volatile solids samples were collected from the aeration chambers of the bioreactors through the side sampling ports (see Figure 5). The suspended and volatile solids analyses were performed according to Methods 209C and 209D, respectively, described in Standard Methods for the Examination of Water and Wastewater (APHA 1989) (referred to hereafter as Standard Methods).

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Gross pollutant analyses

104. BOD samples for the influent and effluent were analyzed using Method 507 of _Standard Methods_. The influent samples for all gross pollutant analytes were collected from the common influent tank that stored the influent for all five reactors. Effluent samples were collected from the individual effluent collection tank of each reactor. DO measurements were made using Method 421F of _Standard Methods_. Triplicate blanks and glucose standards were prepared and analyzed with each BOD test group run. A commercially available bacterial seed, marketed as Polyseed and available from Fisher Scientific, developed for BOD analyses of industrial wastewaters was used as the bacterial seed. This seed was used because a bacterial seed of constant biodegradation potential to the Ninth Avenue contaminants was required and used throughout all phases of this study. If seed from one or all of the bioreactors had been used, as the bacterial consortium became more acclimated to the groundwater composite, the BOD values would have increased due to the increased acclimation of the bacteria to the contaminants.

105. The COD samples were analyzed using EPA Method 410.4 of SW 846 (USEPA 1986). TOC samples were analyzed using Method 505A of _Standard Methods_.

106. Salinity and conductivity were measured using the instructions supplied with the Yellow Springs model 33-S-C-T meter and SCT probe. Salinity and conductivity effluent samples were collected from the common influent and effluent tanks of each bioreactor. The pH of the influent and aeration tanks of each bioreactor was measured using a Fisher pH meter that was calibrated using two-point calibration (pH 4.0 and 10.0 buffers).

Sludge volume index

107. Sludge volume index values were determined by using Method 213C of _Standard Methods_ with one deviation from the prescribed method. This deviation was the use of a 100-ml graduated cylinder instead of a 1,000-ml graduated cylinder, because of the limited amount of mixed liquor available from the bioreactors (the total bioreactor aeration chamber volume was only 2,000 ml).

Priority pollutant analyses

108. Volatile organic compound priority pollutants were collected in 40-ml I-Chem clear volatile vials. VOCs were analyzed using EPA Method SW 846-8270 (USEPA 1986) on a Hewlett-Packard model 5996 mass spectrometry/gas chromatography (MS/GS) system. BNAs were collected in 1-ℓ amber I-Chem brand

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bottles and analyzed using EPA Method 846-8260. BNA samples were analyzed on a Hewlett-Packard model 5985-B MS/GC system. Polychlorinated biphenyl/ pesticide analyses were performed using EPA Method SW 846-8080 on a Hewlett-Packard model 5880 GC system. The analytical detection limits for the standard priority pollutant analysis used in this study and the special EPA- requested priority pollutant analysis with lower analytical detection limits (discussed in Part VI of this report) are presented as Tables B1 and B2, respectively, of Appendix B.

PART VI: RESULTS

Analysis of Test Influents

109. The results of chemical analyses on groundwater composites Nos. 1 and 2 are presented in Tables 3 and 4, respectively. These analyses were performed upon receiving the groundwater samples at WES. Table 5 lists the organic compound analytical results from the analysis of influents throughout various phases of biological studies.

110. The overall quality in terms of priority pollutants of the ground-water composite samples did not change with the substitution of well 14 for well 15 in Composite No. 2 (Tables 3 and 4). Also, the chemical integrity of the two composites did not change appreciably during storage of the samples (Table 5).

111. The gross pollutant concentrations in composite No. 2 were approximately half of those detected in Composite No. 1. The explanation for this reduction is unclear. It is possible that the groundwater quality changed from December 1988 to June 1989; however, a 50-percent change is unlikely. Sample variance from sampling period to sampling period is possible, although a 50-percent deviation is quite high. The difference in gross pollutant concentration in the composite samples is probably a combination of both conditions.

Biological Treatment

112. The unreduced data tables for the acclimation, transitional, AS, and PAC/AS bioreactors are presented in Appendixes C, D, E, and F, respectively. Microscopic observations periodically made during the biological studies and other pertinent laboratory observations and comments are presented in Appendix G.

Acclimation Phase and Transitional Phase

113. The acclimation phase of testing was performed from 17 January 1989 through 10 May 1989. Actual acclimation of the POTW mixed liquor bacteria took approximately 4 weeks. System operating conditions for the acclimation bioreactor are presented in Table 6. Initially, the acclimation

bioreactor was fed only glucose-amended wastewater from the Vicksburg POTW; however, as test time progressed, Composite No. 1 was added to the amended wastewater at varying proportions (see Table 1). The amount of groundwater added was increased at a rate of approximately 0.5 ℓ every other day. As the amount of groundwater composite increased, the proportion of amended waste-water added decreased accordingly to maintain a relatively constant organic loading (BOD) on the system.

114. Table 6 lists the organic loadings in terms of BOD on the system. The organic loading on the system generally increased over time, eventually becoming 0.019 lb BOD/day when the influent was comprised only of the groundwater composite. Table 6 also lists the aeration chamber solids (MLSS and MLVSS) data for the bioreactor.

115. The impact of the groundwater additions on the system is illustrated in Figures 8-16. Influent and effluent BOD concentrations versus test time are presented in Figure 8. The net increases in influent strength as the groundwater additions increased are apparent from Figure 8. The effluent BOD concentrations remained relatively constant even after the system influent was comprised of only groundwater Composite No. 1. The TOC and COD influent and effluent concentrations, which are illustrated in Figures 9 and 10, respectively, did not follow the same trend. Both COD and TOC effluent concentrations increased as the amount of added groundwater increased, indicating the possible existence of refractory chemicals in the groundwater that were difficult to biologically degrade.

116. The aeration chamber salinity also increased with the increased proportion of groundwater making up the influent. This increase is illustrated in Figure 11. The influent salinity (Table 3) is approximately 2,000 mg/ℓ. The salinity concentrations in the aeration chamber were always slightly less than the respective influent salinities.

117. The effect of salinity on the activity of the bacteria is not well understood. Hale and Nyer (1986) investigated the effects of salinity on the biological activity in an AS system that was treating a phenol-contaminated brine groundwater. They concluded that, after an initial lag period, the bioreactor returned to the postsalinity increase perforr¬nce once the bacterial culture became acclimated to the increased salinity. This observation indicates that the addition of low to moderate salinity only temporarily affects AS system biological activity.

118. Admittedly, the removal rates of the gross pollutants decreased with increased salinity, but other factors were also occurring that could affect system performance. These factors include the possible existence of TOC and COD fractions that were not degraded or were slightly degradable or, possibly, the formation of chemical intermediates. Another factor that could have seriously impacted TOC and COD removal was the oxidation of large quantities of iron and manganese in the aeration chamber. From Table 3, the iron and manganese concentrations in groundwater Composite No. 1 are 91.4 and 7.41 mg/ℓ, respectively.

119. As the proportion of groundwater composite to amended wastewater increased, the color of water in the aeration chamber changed from light brown to bright orange. This color change indicted the oxidation of reduced iron and manganese in the aeration chamber. The bulking of the precipitated iron and manganese resulted in a dramatic increase in MLSS concentrations. Figure 12 presents the MLSS and MLVSS concentrations for test days 0 through 45 of the acclimation study. The MLVSS remained relatively constant while the MLSS increased to an eventual constant value of approximately 8,000 mg/ℓ. (The MLSS remained at the 8,000-mg/ℓ level throughout the remainder of the bacterial acclimation study, even after the specialty bacteri- were added.)

120. The increase in MLSS can pose some very serious challenges to an AS system. Increased or elevated MLSS levels in the aeration chamber require more energy for mixing the increased weight of the solids. Visual observations of the bioreactor indicated that mixing efficiency of the aeration chamber was definitely reduced as the MLVSS increased. Reduced mixing efficiency tends to minimize the exposure or contact of active bacteria to soluble contaminants.

121. The effect of the increased aeration chamber fixed solids (non-biologically active solids) on the aeration tank is best illustrated in Figure 13, which presents acclimation system sludge volume index values, percent groundwater in the influent, and effluent TOC concentration versus test time. Initially, the SVI dramatically increased as a small portion of groundwater was added to the system, probably due to the increased organic loading on the system causing an increase in biological activity (e.g., young bacteria have high SVI values due to poor settling). However, as the amount of groundwater in the influent increased, the amount of iron and manganese oxidizing and remaining in the aeration chamber increased.

122. An analysis of the waste sludge for total iron and manganese was made on test day 69. The iron and manganese concentrations in the waste sludge were 35,700 and 1,510 mg/kg, respectively. These extremely high concentrations of iron and manganese substantiated the observation that significant oxidation of the reduced iron and manganese entering in the influent was occurring in the aeration chamber.

123. The increase in aeration chamber fixed solids lowered the SVI by enhancing the settling characteristics of the mixed liquor. The large amount of fixed solids in the aeration chamber increased the settling rate of the MLSS by forcing the VSS, which is the fraction of the MLSS that settles slowest, downward as the fixed solids settled. From Figure 13, the effluent TOC increased with increased groundwater addition with a respective decrease in SVI. In summary, the increase in effluent TOC was probably due to reduced mixing efficiency in the aeration chamber and to an increase in the percentage of TOC in the influent that is difficult to degrade.

124. The addition of the specialty bacteria (Super Cee) to the bioreactor began on test day 49 and continued through test day 67. The observed TOC, COD, and BOD removals did not change with the addition of the commercial bacteria. The observed TOC, COD, and BOD removals achieved throughout the acclimation phase are illustrated in Figures 14-16. From the figures, it is apparent that the addition of the specialty bacteria had little effect on system performance.

125. Table 7 lists the priority pollutant concentrations detected in the bioreactor influents and effluents at various test days during the acclimation study. Test day 54 was before the specialty bacteria was added to the system. The test day 112 analysis was requested by the USEPA to evaluate the quality of the effluent using lower analytical detection limits than those previously used. An increase in the removal of priority pollutant organics was not observed after specialty bacteria addition, because all of the priority pollutants, except two phthalates, were being removed to concentrations below the higher analytical detection limits used during the test day 54 analysis. The test day 112 analysis did detect several other organics not previously detected in the effluent. These concentrations are lower than the analytical detection limits used in the test day 54 analysis. These organics could have also been present in the effluent of the bioreactor prior to the addition of the specialty bacteria but at concentrations lower than the analytical detection limits used. In general, the acclimated Jackson POTW

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bacteria performed sufficiently in removing all of the priority organic pollutants, making the addition of the specialty bacteria (Super Cee) not an attractive option, unless a possible reduction in acclimation time during pilot or full-scale start-up is desired.

126. During the transitional period, the number of observation well groundwater samples contributing to the composite sample was reduced from six wells to only one well (No. 20). (As mentioned in Part V, the transitional period was that test period when the mixed liquor from the acclimation tank was poured into four smaller bioreactors in anticipation of the arrival of Composite No. 2 groundwater samples.) The strength of influent decreased with decreasing number of groundwater samples comprising the influent.

127. Figure 17 presents BOD concentrations versus test day for the influent and effluents from bioreactors Nos. 1 and 2. The test days presented in Figure 17 are numbered from the first day of operation of the bioreactors until the beginning of the AS phase of the biological studies at test day 88. The strength of the influent decreased from a maximum influent BOD concentration of 2,600 mg/ℓ on test day 42 to a minimum influent BOD concentration of 405 mg/ℓ on test day 57. The respective effluent BOD concentrations for bioreactors Nos. 1 and 2 decreased from maximum values of approximately 145 to below 20 mg/ℓ, which correlated well with the reduction in influent BOD concentration.

128. When the second shipment of groundwater samples arrived, well 20 was replaced with Composite No. 2 as the system influent. Upon using Composite No. 2 as the system influent, influent BOD concentrations increased from 405 mg/ℓ (influent was comprised of only well 20) to approximately 1,700 mg/ℓ. The effluent BOD concentrations of both bioreactors increased with increasing influent strength. Figure 18 presents the BOD data for bioreactors Nos. 3 and 4. The same trend of reduced effluent BOD concentrations with reduced influent BOD was observed. It must be noted that the HRT during the transitional period on test day 45 was increased to 2 days to conserve Composite No. 1 influent until the sample of Composite No. 2 wells arrived. On test day 64, the HRT was decreased to 1.0 day with the arrival of the second groundwater sample shipment.

129. Figure 19 presents MLVSS values and influent and effluent BOD concentrations versus test time for bioreactor No. 3. The MLVSS concentrations in the bioreactor decreased as influent BOD concentration decreased, as

illustrated in Figure 19. These data were representative of all four bioreactors.

130. Figure 20 presents solids data versus test day for bioreactor No. 1, which had a SRT of 2 days; therefore, the amount of fixed solids is kept relatively low due to the amount of sludge wasted daily. Figure 20 shows that the MLSS and MLVSS decreased from test day 20 through test day 40. With the changes in HRT over time, the MLSS was varied while MLVSS tended to increase with increasing HRT. On test day 57, when the influent consisted primarily of well 20, the MLSS and MLVSS began to decrease. The reduction in MLSS on test day 67 is not surprising because the iron and manganese concentrations in well 20 are less than the other wells previously used to formulate the composite influent. Also, decreased MLVSS is not surprising because of the decrease in influent BOD (the influent at this point consisted of only well 20), which resulted in reduced biological activity.

131. The bioreactor No. 2 MLSS and MLVSS data (presented in Figure 21) followed the same trend as the bioreactor No. 1 data, except that the MLSS remained higher throughout the transitional period. This is not surprising considering that bioreactor No. 2 has a SRT of 4 days; therefore, less fixed solids were wasted daily. The MLVSS remained relatively constant throughout the transitional period, with a slight increase when the HRT was increased, then decreasing when the influent consisted only of well 20.

132. Figures 22 and 23, respectively, present the MLSS data for bioreactors Nos. 3 and 4. These data follow the same trends as the data for bioreactors Nos. 1 and 2 (i.e., higher MLSS with the higher SRTs). The MLVSS of these bioreactors also experienced an increase with increasing HRT, and then decreased when the influent BOD concentration decreased.

133. In summary, the effluent BOD concentrations decreased with decreasing influent BOD. The MLVSS concentration exhibited a lag (approximately 10 days) before decreasing. This decrease occurred after the influent and effluent BOD values had decreased. As the influent BOD strength increased, the effluent BOD and MLVSS also increased, and the MLVSS showed a similar lag with the decreasing influent BOD strength before the MLVSS eventually increased. The rebound of the MLVSS with increased influent BOD concentration after a period of reduced influent BOD highlights the apparent ability of the AS system to respond favorably to fluctuations in influent quality. This is important because, during full-scale treatment of the groundwater, fluctuations in influent quality are expected. Thus, the data collected

during the transitional phase indicated that the AS process is flexible enough to maintain a good-quality effluent, even with fluctuations in influent BOD concentration.

Activated Sludge

134. The AS study was performed from the period 7 August 1989 through 19 September 1989. The average operating parameters and conditions for the four bioreactors are presented in Table 8.

135. The ratios of MLVSS to MLSS (MLVSS/MLSS) were all below 0.5 (Table 8). Typical AS systems treating municipal wastewater have MLVSS/MLSS ratios in excess of 0.6 (Metcalf and Eddy, Inc. 1979). The oxi'ation of iron and manganese in the influent significantly increased the aeration chamber fixed solids concentrations, resulting in elevated MLSS values. As expected, the MLVSS of the bioreactors increased with increased SRT.

136. The percent removals of the gross pollutants are presented in Table 9. There was no appreciable difference between the performance of the four bioreactors for the removal of the gross pollutants.

137. Figure 24 presents the percent removals of the three gross pollutants of each of the four bioreactors versus bioreactor SRT. As stated earlier, bioreactors Nos. 1, 2, 3, and 4 had SRTs of 2, 4, 8, and 16 days, respectively. Bioreactor No. 3 had the lowest percent TOC and COD removals. However, from Figure 24, it can be seen that the difference between bioreactor performance for the removal of the gross pollutant is not significantly different. Therefore, it was concluded that at a HRT of 1 day, there was not an appreciable difference in gross pollutant removals for the range of SRTs evaluated.

138. Results of the two priority pollutant analyses of the effluents from the four bioreactors are presented in Table 10. The first analysis was performed on samples collected during week 3 of AS testing. More organic compounds were detected in the effluent of bioreactor No. 3 then in the effluents of the other three bioreactors. However, except for acetone, the concentrations of the organic compounds detected in the bioreactor No. 3 effluent were all near the analytical detection limit for the majority of the contaminants. The second analysis of effluents from the four bioreactors indicated that concentrations of organic compounds detected were all near the analytical detection limits of the respective compounds.

139. An analysis of organic priority pollutants was made on a composite sample of waste sludge from four of the AS bioreactors. Results are presented in Table 11. There were surprisingly high concentrations of organic compounds in the waste sludge. The impact of these concentrations in terms of disposal is not known. Waste sludge from a full-scale system may not have the same concentrations; therefore, these analyses should be used only as an indication of a potential problem during site remediation. If higher SRTs are used during the pilot or full-scale studies, such that the AS system extends into the extended aeration mode or a sludge digester (aerobic or anaerobic) is used to reduce the volume of sludge that requires disposal, many of the contaminants detected in the waste sludge will probably be further degraded.

140. The results of the gross pollutant and priority pollutant organics analyses of the AS bioreactors showed that the four smaller bioreactors performed relatively poorer than did the acclimation bioreactor. Three factors could have been individually or jointly responsible for the differences in effluent qualities between the acclimation bioreactor and the four smaller bioreactors. First, there is a hydrodynamic difference between the large and small bioreactors. The acclimation bioreactor appeared visually to have a better mixing efficiency than the smaller bioreactors (the large bioreactor had a larger porous stone). Improved mixing efficiency could improve the amount of contact between the bacteria and the contaminants in the aeration chamber of the larger bioreactor.

141. Second, the smaller bioreactors were operated at higher HRTs than the acclimation bioreactor. The transitional period indicated that MLVSS increased and the effluent BODs decreased with an increase in HRT. Some of the TOC and COD could require more contact time for complete degradation.

142. Finally, Composite No. 2 consisted of harder to degrade compounds than Composite No. 1. A review of Tables 3 and 4 indicates the presence of more individual priority pollutant organic compounds in Composite No. 2 than those detected in Composite No. 1, especially chlorinated hydrocarbons which are very difficult to degrade. The presence of these compounds could result in higher effluent TOC and COD concentrations.

143. Based on the results presented in Table 9, the control reactor demonstrated appreciable removals of gross pollutants. During the initiation of AS testing, this reactor experienced a large increase in not only MLSS, as expected due to the cations in the influent oxidizing in the aeration chamber, but also in MLVSS. This was paralleled with an increase in the number of

observations of eucaryotic (multicellular) organisms such as rotifers and ciliates and procaryotic (unicellular) organisms such as bacteria, based on microscopic observations of the water taken from the aeration tank. Organisms much too small to identify using a standard laboratory microscope were observed in the aeration chamber water of the control reactor and also in untreated groundwater Composite No. 2 samples (groundwater Composite No. 1 samples were not studied under a microscope). Since, the control reactor MLVSS increased only a few hours after removing all solids from the reactor, it was concluded that the groundwater contained a population of microorganisms capable of surviving the aerobic conditions that exist in an AS bioreactor.

144. Precautions were taken to ensure that cross-contamination between the AS bioreactors and the control reactor was not occurring, resulting in the inoculation of the control reactor with biomass from the bioreactors. Probes and thermometers that were used in the bioreactors were not put into the control reactor. However, the control rector always experienced an increase in MLVSS in relatively short times after removing all of the solids from the reactor. Since the existence of bacteria in the control reactor was verified by increased MLVSS values and multicellular organisms in the aeration chamber mixed liquor, the percent removal of the gross pollutants and the priority pollutants achieved in the control reactor was not used to estimate the amount of off-gassing of contaminants that had occurred in the AS bioreactors. The existence of the bacteria in the control reactor and possibly in the groundwater composite is important, because bacteria native to the site can greatly assist in establishing an acclimated bacterial population during pilot- or full-scale biological treatment implementation.

145. The gross pollutant and MLVSS data from the AS study were used to determine the cell yield coefficient (Y) and the endogenous decay rate (k_d) of the bacterial culture using a graphical approximation method described by Metcalf and Eddy, Inc. (1979). The inverse of the bioreactor SRTs (1/SRT) were plotted against the change in BOD (S_o - S) for each bioreactor divided by product of the MLVSS of each bioreactor times HRT. Plots of these parameters for TOC, COD, and BOD are presented as Figures 25-27. According to Metcalf and Eddy, the slope of the best fit line is Y , while the y-intercept is k_d . Table 12 lists the Y and k_d values determined from plotting the gross pollutant and MLVSS data using the graphical approximation methods. The respective r^2 values of the regression analysis are also listed in Table 12.

146. The Monod saturation constant (K_s) and maximum growth rate (u_m) were determined using the gross pollutant and MLVSS values of each bioreactor. These constants were estimated using graphical approximation methods described by Grady and Lim (1980). The method involves plotting bioreactor effluent concentrations (X-axis) versus bioreactor effluent concentrations divided by the sum of the inverse of SRT and k_d (y-axis). The plots used to make the graphical approximations are given in Figures 28 and 29. The estimated values of K_s and u_m are listed in Table 12. The K_s and u_m values could not be estimated using the TOC data because the bioreactors had very similar TOC effluent concentrations. These coefficients could have possibly been determined using the TOC data, if the bioreactors had been operated using a wider range of SRTs, a decreased HRT, or by operating the cells with varying influent contaminant concentrations.

147. The estimated values in Table 12 are in general agreement with those values reported by Kincannon et al. (1989). The Y and k_d regressions basically all had good statistical fit, while the K_s and u_m regressions all had very poor statistical fit. The r^2 values for the BOD data for both regressions had a better fit than the other two analytes.

Air Stripping

148. Figure 30 presents the TOC removal versus cumulative test time for both air stripping units using Composite No. 1. These data were collected during the operation of the units at 20° C and a pH of 6.8 (unadjusted pH). Figure 30 indicates that the TOC values dropped initially, then began increasing as the test proceeded. Two factors (and probably a combination of the two) were the suspected cause for this observation. The first factor was the precipitation of oxidized iron and manganese in the packed column. After only a few minutes of operation, a reddish-orange solid began to appear in the column packing and continued to accumulate with time. These solids were typical of the oxidized iron and manganese observed in the aeration chambers of the AS bioreactors. The oxidized cations in the column packing could have adsorbed organic compounds as they were volatilized from solution in the column. As the test proceeded, the oxidized iron and manganese possibly could have released the sorbed organics into the water flowing by in the column.

149. A definite trend with both replicates tends to indicate that some type of chemical or physical phenomenon was occurring, causing the TOC data to

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decrease, then slowly increase over time. Opposing this explanation is the question of why the organic compounds would adsorb then desorb into the same water, since the air stripping units are operated in a batch mode.

150. A second explanation for the TOC behavior as shown in Figure 30 is that the TOC analytical methods used to develop these data are questionable for analyzing water containing high levels of volatile compounds. The TOC analytical method commonly used involves a sample purging step that does not account for the loss of volatiles. The COD test methods also require a purging step that can potentially strip much of the volatile fraction out of solution. Therefore, the gross pollutant analytical methods for the air stripping studies yielded concentrations that were highly suspect (BOD was not run because this analysis required too much sample). After the TOC stripping data and TOC and COD analytical methods were evaluated, the decision was made by WES engineers to cancel the duplicate COD air stripper test runs. Instead, a single replicate COD run was made, because the results of the COD run were suspect.

151. Limited reliability was also put in the AC TOC and COD data. However, since the water in the aeration chambers of the AS and PAC/AS bioreactors was aerated for 24 hr, the TOC and COD from the biological studies were considered acceptable for this study.

152. The COD air stripping test run data are presented in Figure 31, which shows COD removal versus cumulative test time. Composite No. 2 was used during the single replicate COD run. The COD fraction of the groundwater that is volatile cannot be estimated from these data because of the slow desorption rate of the COD from the water. The slow desorption kinetics indicate that COD removal is theoretically feasible, but will take too long to be practical as a method for removing the volatile fraction of COD. Again, it must be stressed that there is little confidence in the suitability of the COD test for estimating total VOC concentrations.

153. To quantify the extent of VOC removal from the air stripping units, all of the VOC concentrations determined using the MS/GC analysis were summed and referred to as the total volatile organic contaminants (TVOCs) concentration. This parameter was used to evaluate the desorption kinetics of the VOCs from the groundwater into the vapor phase during air stripping treatment. The change in TVOC concentration versus cumulative test time for both runs is illustrated in Figure 32.

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154. Table 13 presents the air stripping TVOC desorption data for both duplicate TVOC runs. Composite No. 2 was used for the duplicate TVOC runs. The table lists test times, raw concentration data (C/C_o), and the relative loss of water due to evaporation (W/W_o). The F_t term in the table is defined by Thibodeaux (1974) as the fraction of the total amount of the volatile chemical constituents remaining in the wastewater at time t. The F_t term is mathematically defined as $C_t M_t / C_o M_o$.

155. As described by Thibodeaux, the F_t values are plotted against the $1 - W/W_o$ for each test time interval on a log-log plot. The slope of the best line is equal to the relative volatility of the TVOC to water $(K_{s/a})$. This value was estimated using linear regression to be 34.7 and 67.1 with respective correlations of fit values (r^2) of 0.96 and 0.94, for run Nos. 1 and 2, respectively. The run No. 1 data indicate that the TVOC fraction of the groundwater desorbs from the water at a rate approximately 0.5 times the rate determined from the run No. 2 data. Therefore, to be conservative, only the run No. 1 data were further evaluated. The run No. 1 F_t data log-log plot is presented as Figure 33.

156. A review of the desorption results reported by Thibodeaux (1974) indicates that the TVOC behaves very similarly to acetone. This result is not surprising since the TVOC component of the groundwater consisted predominantly of acetone and 2-butanone. Sullivan, Lenzo, and Johnson (1985) evaluated air stripping of 2-butanone. Their results indicated that 2-butanone can be air stripped using high air-to-water ratios (>100) and by heating the influent to the air stripping unit to temperatures in excess of 60° C.

157. The HNU readings taken during the air stripping test runs varied according to placement of the HNU probe in relation to the off-gassing port of the column and whether the fume hoods in which the air stripping units were used were operating while taking the HNU readings. The HNU readings at the initiation of testing ranged from a high value of 220 ppm to a low reading of 2.5 ppm. The HNU readings at the end of testing ranged from 60 to 0.4 ppm. These values indicated that some VOCs were exiting the columns and there is potential for high concentrations of VOCs to be present in the off-gases from an air stripping unit. HNU readings are instantaneous and do not represent the true flux of TVOCs from the column, as do the TVOC desorption data. Therefore, the interpretation of the HNU reading is that the potential for air pollution due to the off-gassing of contaminants does exist and that, based on

the desorption data, some volatilization of TVOC is occurring. However, this occurs at a slow rate, making air stripping not very attractive.

158. In summary, high concentrations of oxidizable cations in both groundwater composite samples indicate a potential for serious operational problems during air stripping treatment of wastewaters. High concentrations of oxidizable cation concentrations are defined as those concentrations that will result in the clogging of the aeration column. If air stripping is going to be evaluated further for treatment of the Ninth Avenue groundwater, some means of removing the iron and manganese from solution (such as ion exchange or precipitation) will have to be evaluated. Also, the desorption rate of the TVOC from the groundwater may be increased if the influent to the stripping unit is heated to temperatures in excess of 60° C.

Activated Carbon

159. The required adsorption equilibrium time was determined by the methods discussed in Part II for VOCs, BNAs, COD, TOC, and BOD. Composite No. 1 was used as the test liquid for the equilibrium time determinations. The results of this phase of AC testing are illustrated in Figures 34 and 35.

160. After reviewing the TOC adsorption equilibrium data (Figure 36), there was some concern that all of the available adsorption sites on the 10.0-g dose were filled and that true adsorption equilibrium may require more time. Therefore, a second TOC adsorption equilibrium test using a 30-g dose was performed.

161. The results of the 30-g dose tests are summarized in Figure 37. It can be seen from a review of Figures 34-37 that, at approximately 2 hr, adsorption equilibrium was reached, regardless of the quantity of AC used. This estimate was further supported by reviewing the plots (Figures 38-40) for test times 0.0 through 8.0 hr. Therefore, 2.0 hr was selected as the amount of time required for the AC/groundwater slurries to reach chemical equilibrium while tumbling.

162. The AC adsorption equilibrium batch data were developed according to the methods described previously in Part II. These data are presented in Table 14. The BNA organic compounds were evaluated using the sum of all BNA compounds for this study, which was identified as the total base-neutral/acid extractable (TBNA) concentration. The VOC data were evaluated separately by contaminant (acetone and 2-butanone) and as TVOC. These data were plotted on

Cartesian coordinates to evaluate the change in aqueous phase concentration (C) over a range of AC loadings (X/M). The C concentrations were determined using chemical analysis of the aqueous solutions after tumbling the slurries for the equilibrium time. The X/M values were determined mathematically using a system mass balance of the contaminant for each given C. The C versus X/M plots are presented as Figures 41-46.

163. The Freundlich adsorption model was used to mathematically describe the adsorption kinetics. The Freundlich equation is presented below.

$$q = k * C^{(1/n)} \tag{3}$$

where

q = equilibrium AC contaminant concentrations, mg/kg

k = Freundlich loading constant, mg/g

C = equilibrium aqueous phase concentrations, mg/ℓ

n = Freundlich constant, dimensionless

164. The Freundlich can be linearized to determine the Freundlich constants using graphical approximations described below.

$$\ln q = \ln k + 1/n * \ln C \tag{4}$$

165. The data are plotted on log-log coordinates. Figures 47-52 were used to develop AC adsorption isotherms for each respective analyte. From the adsorption isotherms, the Freundlich constants were estimated using linear regression of the isotherms. The Freundlich isotherm model constants for each analyte are listed in Table 15, along with the r^2 values for their respective linear regressions.

166. The TOC and COD Freundlich isotherm constants seem reasonable, based on a review of the results of the adsorption equilibrium batch tests plotted in Figures 45 and 46. From these figures, it can be seen that as small changes in C occur, large changes in X/M will occur, indicating little TOC and COD AC adsorptive capacity.

167. One reason for the low estimated adsorptive capacity of the AC for TOC and COD may be the interfering effects of the oil and grease in the groundwater composite. The Ninth Avenue site groundwater is extremely complex, containing many organic compounds, such as oil and grease, that have

very different adsorptive properties. The differences in multichemical component adsorptive capacities are shown in Figures 45 and 46. Some data points on these plots indicate a relatively high adsorption capacity, while other data points indicate low adsorption capacity. These plots are typical of wastewaters containing many organic compounds with variable adsorptive characteristics.

168. Table 16 lists the Freundlich isotherm constants for the analytes, various example aqueous phase concentrations (C), and their respective X/M values estimated using the Freundlich model. These AC loading concentrations can be used to estimate AC capacity for each respective C . However, care should be used when evaluating AC loadings using this method, especially when estimating X/M of the water treated by other treatment processes prior to AC treatment (i.e., AC used as a polishing unit). Treatment of the groundwater by other treatment systems, prior to AC treatment, could significantly affect the adsorptive characteristics of the influent, thereby changing the observed X/M values.

169. Based on the results of this study, AC seems to have a low adsorptive capacity for the site groundwater contaminants. The X/M values determined during the AC study are strictly theoretical and should be used as a rough indication of treatment feasibility. Activated sludge treatment of complex wastewaters is better evaluated using column evaluation methods. This is especially true for the Ninth Avenue site groundwater, because of its high degree of chemical complexity. The isotherm method of evaluating AC is much better suited for pure chemical solutions that are strictly equilibrium controlled (far below the solubility limit of the contaminants) with no adsorptive competition. Adsorption isotherm evaluation of Composite No. 2 was used only as an initial evaluation of the feasibility of AC treatment (with the assumption that pilot-scale testing would follow). Therefore, pilot-scale testing is recommended for a more complete evaluation of AC.

Powdered Activated Carbon/Activated Sludge

170. The operating parameters and treatment conditions for the PAC bioreactors and the control bioreactor are presented in Table 17. The control bioreactor for the PAC/AS study was the 8.0-day SRT bioreactor from the AS study (bioreactor No. 3). From Table 17, the PAC bioreactors and control

bioreactor were operated at a HRT of 1 day and a SRT of 8 days (hence, the selection of AS bioreactor No. 3 as the control).

171. An 8.0-day SRT was selected because relatively small differences were observed during the AS study between the qualities of the AS bioreactor effluents. Of the four bioreactors evaluated in the AS study, the 8.0-day SRT bioreactor (bioreactor No. 3) had the lowest percent removals of TOC and COD. A SRT of 8.0 days was selected to evaluate the benefit of PAC addition to a biological system that was not removing extremely high percentages of the TOC and COD.

172. The selected PAC doses are listed in Table 17 as the powdered activated carbon suspended solids (PACSS) concentrations. This parameter is the measure of the amount of PAC solids in PAC/AS bioreactor and is based on the daily input of PAC to the bioreactor and the SRT. Mixed liquor suspended solids were calculated using the following equation:

$$MLSS = TSS - PACSS \tag{5}$$

where

$\quad$ MLSS = mixed liquor suspended solids, mg/ℓ

$\quad$ TSS = total suspended solids, mg/ℓ

$\quad$ PACSS = PAC suspended solids, mg/ℓ

173. Table 17 lists the ratios of MLVSS/MLSS for each PAC/AS and control bioreactor. As PAC dose increased, the MLVSS and VSS/SS ratios also increased, indicating an overall rise in biological activity with increasing PAC dose.

174. Figure 53 illustrates the effect PAC dose had on the SVI of each PAC/AS bioreactor. There was a marked increase in SVI with the addition of the PAC, even with the 1,000-mg/ℓ PAC dose (PAC/AS bioreactor No. 1). However, there was an appreciable difference between the 8,000-mg/ℓ dose (PAC/AS bioreactor No. 4) and the other PAC/AS bioreactor SVIs. From Figure 54, with increasing PAC dose, the PAC surface area available for support of bacterial growth and food adsorption also increased, resulting in increased biological activity. These increased SVIs coincided with the increased biological activity exhibited by all of the PAC/AS bioreactors. These results strengthen the observation that increased PAC dose complements the biological activity of the AS process.

175. Several explanations for the increase in biological activity with increased PAC dose have been theorized. First, the PAC is removing inhibitory compounds, such as the chlorinated hydrocarbons, from the aeration chamber aqueous phase, resulting in contaminated water more conducive to biological activity. Once adsorbed onto the PAC, the sorbed compounds can be degraded by attached-growth organisms that are physiologically similar to the suspended-growth organisms. These attached-growth organisms use the PAC as a support substrate and the adsorbed organics as a food substrate. This theory fully agrees with the work of Hamoda and Fahim (1984), who also theorized that PAC complemented the work of AS for treating domestic wastewater by providing a support substrate and concentrated food source. Zappi, Adrian, and Francingues (1990) postulated that carbon fines in groundwater recharge wells tend to concentrate organic contaminants, resulting in a particle that can structurally support attached bacterial growth while serving as a source of concentrated organic compounds.

176. The second possible explanation for the increase in biological activity with increased PAC dose is the possibility of a physiologically different culture of attached-growth bacteria growing on the PAC solids. This attached growth population could be more acclimated to the contaminants that are not readily degraded from the aqueous phase by the suspended growth culture, but adsorbed onto the PAC. As PAC dose increases, the amount of PAC surface area available for growth of the different bacterial community increases, resulting in an increase in biological activity.

177. Finally, the PAC could be adsorbing many of the volatile contaminants that were previously off-gassing from the AS bioreactors. Once adsorbed, the VOCs can be used by the bacteria as an additional food source, that was not available previously, due to rapid volatilization from the AS bioreactors. As the PAC dose increased, the overall adsorptive capacity of the bioreactors also increased, thereby increasing the amount of food available to the bacteria.

178. Table 18 lists the results of priority pollutant analysis of the four PAC/AC bioreactors and the results from the same analysis of the control during the AS study. No appreciable differences were noted in priority pollutant removal among the bioreactors. PAC bioreactor No. 4 (8,000-mg/l PAC dose) did not have any of the phenolic compounds detected in its effluent, possibly indicating slightly better priority pollutant removal.

179. The results from the gross pollutant analysis of the influents and effluents from the PAC and control bioreactors are presented in Table 19 and are illustrated in Figure 50. The percent removal of TOC and COD increased dramatically with increasing PAC dose. The percent removals of the gross pollutants also increased with increasing VSS/SS ratios, as illustrated in Figure 55. As the VSS/SS ratios increased, the removal of TOC and COD also increased, as shown in Figure 55. The BOD removals were already high; therefore, only a slight improvement in removals was observed with increased PAC dose (see Figures 54 and 55).

180. During the PAC/AS study, the PAC/AS bioreactors influent and effluents were analyzed for oil and grease (O&G) concentrations. These data are presented as a plot of C/C_0 versus PAC dose in milligrams per liter in Figure 56. As the PAC dose increased, the removal of O&G also increased.

Limitations on Use of Laboratory Study Results

181. It is necessary to recognize several limitations to this study in order to fully utilize the results for evaluating the feasibility of each of the candidate technologies for treatment of the contaminated site groundwater. Combinations of treatment technologies were not evaluated; therefore, the efficiency of each technology for the removal of residual concentrations of contaminants remaining in the effluent of another treatment technology cannot be estimated based on the results of this study.

182. The test influents used in this study are highly contaminated and chemically complex, such that extrapolation of the results of this treatability study to a much lesser contaminated water would be difficult.

183. The biological studies were much more complex than the AC and air stripping evaluations. Also, comparison of various biotechnology system configurations, such as attached-growth versus suspended-growth systems, was not performed. One limitation of the biological studies was that a true mass balance of the contaminants around the bioreactors was not made. A true mass balance would allow for a comparison of biological treatment versus off-gassing and/or PAC adsorption. However, the value of differentiating what removal process is responsible for removal/degradation of the contaminants is questionable at this time. The final limitation of the biological treatability studies was that the formation of possible intermediates was not evaluated, although the high TOC and COD removals achieved during the PAC/AS

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bioreactor study indicated that a large portion of the total available organic matter was being removed.

184. The AC and air stripping studies were less intense than the biological studies. In light of the chemical complexity of the groundwater composite samples used in the treatability studies, AC is probably not as attractive as biological treatment. However, the chemical complexity of the groundwater influent may be much less during actual site remediation than that experienced during the treatability study. Air stripping could be further evaluated by changing the air-to-water ratios and/or increasing the system temperature. However, pretreatment of an influent to the air stripper for cation removal will still be required.

185. In summary, care should be taken when trying to extrapolate the results of a bench-scale feasibility study to full-scale field implementation. Pilot testing is required as the next logical step to develop appropriate design criteria and to properly evaluate full-scale system performance.

PART VII: CONCLUSIONS

186. The bacterial acclimation phase of the biological studies indi-
cated that an inoculum from an activated sludge treatment system treating
municipal wastewater could be acclimated to the contaminants in the Ninth
Avenue Dump Site groundwater composite samples. Reduced iron and manganese in
the groundwater caused a dramatic increase in the aeration chamber solids
concentrations due to cation oxidation.

187. Reduced influent organic strength did not have a negative effect
on the acclimated bacteria. During a period of low organic carbon concentra-
tions in the influent, the mixed liquor volatile suspended solids decreased.
Once the influent organic carbon concentrations increased (Composite No. 2),
the biological activity in the bioreactor responded favorably with an increase
in MLVSS.

188. The activated sludge process indicated a potential for removal of
contaminants from the Ninth Avenue Site groundwater. BOD removals were always
in excess of 95 percent. However, TOC and COD removals were only in excess of
50 percent. Few priority pollutants were detected in the effluents of the
bioreactors. The priority pollutants detected were at concentrations very
near their analytical detection limit. The addition of a commercially avail-
able bacteria (Super Cee) did not increase the removal of any of gross or
priority pollutants.

189. The addition of PAC to the activated sludge units improved the
removal of the gross pollutants when compared to the AS bioreactors. The per-
cent removal of the gross pollutants increased with increased PAC dose. A PAC
dose of 8,000 mg/ℓ resulted in percent removals exceeding 85 percent for all
of the gross pollutants in groundwater Composite No. 2. Fewer priority pol-
lutants were detected in the 8,000-mg/ℓ PAC dose bioreactor effluent than in
any of the other bioreactors.

190. The activated carbon evaluated had a low adsorptive capacity for
the contaminants in the groundwater Composite No. 2. The low adsorption
capacity experienced with the activated carbon is not surprising considering
the types of contaminants (low molecular weights) found in the site ground-
water. However, activated carbon may be feasible for use as a polishing
treatment. The adsorptive capacity of the carbon may increase with the
removal of some of the contaminants. The adsorption data indicated that the

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groundwater contains organic compounds of very different adsorptive characteristics.

191. Air stripping exhibited a low potential for efficiently removing the contaminants from the Ninth Avenue Site groundwater. The oxidation of cations (Fe and Mn) in the packed column will pose significant operational problems. Pretreatment of the influent to an air stripping unit for the removal of the cations will be required if air stripping is selected.

192. In summary, activated sludge treatment augmented with the addition of powdered activated carbon seems to be the most technically promising treatment technology evaluated. From the literature reviewed and the results of this study, activated carbon may be suited best as a polishing unit to ensure that priority pollutants do not escape treatment under high organic loading and to remove residual TOC and COD from the effluent of the biological treatment system.

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Table 1

Acclimation Study Influent Wastewater and Groundwater Composition

| | Influent Component Amounts | |
| | Wastewater | Groundwater |
Test Day	ℓ	ℓ
0	15.0	0.0
1	13.5	0.5
2	13.5	0.5
3	12.0	1.0
4	12.0	1.0
5	10.5	1.5
6	10.5	1.5
7	9.0	2.0
8	9.0	2.0
9	7.5	2.5
10	7.5	2.5
11	6.0	3.0
12	6.0	3.0
13	4.5	3.5
14	4.5	3.5
15	4.0	3.0
16	4.0	3.0
17	1.5	4.5
18	1.5	4.5
19	1.5	4.5
20	0.0	5.0
23	0.0	5.0

Table 2

Biological Studies Sample Matrix

Analyte	Influent	Aeration Chamber	Effluent
Temperature	--	Daily	--
DO	--	Daily	--
Salinity	Daily	Daily	Daily
Headspace VOCs (HNU)	Daily	Daily	--
BOD5	2WK*	--	2WK
COD	2WK	--	2WK
TOC	2WK	--	2WK
Nutrients	2WK	--	2WK
MLSS	2WK	--	2WK
MLVSS	2WK	--	2WK
VOCs	Every 3 WKS	--	Every 3 WKS
BNAs	Every 3 WKS	--	Every 3 WKS

* Sampled twice weekly.

Table 3

Chemical Analysis of Groundwater Composite No. 1

Analyte	Concentration (mg/ℓ)
Priority Pollutants	
Methylene chloride	11.00
cis-1,2-dichloroethane	16.00
2-butanone	260.00
Acetone	18.00 J*
Toluene	10.00
Phenol	0.27
2,4-dimethylphenol	0.63
2-methylphenol	0.80
4-methylphenol	0.81
Metals	
Aluminum	1.08
Arsenic	0.01
Barium	0.32
Boron	2.11
Cadmium	0.01
Calcium	589.00
Chromium-III	0.11
Cobalt	0.06
Iron	91.40
Nickel	0.48
Lead	0.04
Magnesium	234.00
Manganese	7.41
Potassium	37.70
Zinc	0.88
Miscellaneous Analytes	
BOD5	2300
COD	5010
TOC	1260
pH	6.78
O-phosphate	0.601
T-phosphate	0.912
TKN	76.8
Ammonia	73.2
Nitrate	0.022
Sulfate	93.3
Chloride	566
Fluoride	3.41
Salinity	2,400

* Indicates concentration is below statistical quantitation limits.

Table 4
Chemical Analysis of Groundwater Composite
Sample of Shipment Two

Contaminant	Concentration mg/ℓ
Priority Pollutants	
Methylene chloride	1.3
cis-1,2-dichloroethene	12.2
Toluene	9.0
2-butanone	296.0
Acetone	16.3J
T-xylene	1.7
Isophorone	0.023 J*
Vinyl chloride	4.5
4-methyl-2-pentatone	25.0
Phenol	1.572
2,4-dimethylphenol	1.195
2-methylphenol	2.612
4-methylphenol	5.75
Miscellaneous Analytes	
BOD5	1,729
COD	3,279
TOC	745
pH	6.83
Conductivity	4,195
O-phosphate	5.7725
T-phosphate	13.57
TKN	88.4
Ammonia-N	75
NO$_2$	0.00805
Salinity	2,900

* Indicates concentration is below statistical quantitation limits.

Table 5
Comparison of Biological Test Influents

Analyte	Acclimation mg/ℓ	Activated Sludge mg/ℓ	PAC/ Activated Sludge mg/ℓ
Methylene chloride	11	1.3	1.3
Vinyl chloride	ND*	4.5	ND
1,1-dichloroethane	ND	1.1	ND
cis-1,2-dichloroethane	16	12.2	12.2
Toluene	10	9	ND
Ethylbenzene	ND	0.43 J**	ND
T-xylene	ND	1.7	ND
2-butanone	260	296	
Acetone	16 J	16.3 J	ND
Isophorone	ND	0.023 J	0.040 J
4-methyl-2-pentanone	ND	25	ND
Phenol	0.27	1.572	0.86
2,4-dimethylphenol	0.63	1.195	1.65
2,4-dichlorophenol	ND	ND	0.85 J
Benzoic acid	ND	ND	5.68
2-methylphenol	0.8	2.612	1.87
4-methylphenol	0.81	5.754	6.07

* Not detected.
** Indicates concentration is below statistical quantitation limits.

Table 6

Acclimation Bioreactor Operating Parameters
During Consortium Acclimation to Site Groundwater

Test Day	Influent Component Amounts Sewage ℓ	Ground H2O ℓ	HRT days	SRT days	SS mg/ℓ	VSS mg/ℓ	VSS/SS	Influent BOD mg/ℓ	Effluent BOD mg/ℓ	F/M mg/mg	Organic Loading lb. BOD/day
0	15.0	0.0	1.001	10	933.3	723.2	0.77	202	16	0.28	0.007
1	13.5	0.5	1.073	10	778.3	633.3	0.81	211	33	0.31	0.006
2	13.5	0.5	1.073	10	786.7	640.0	0.81	365	--	0.53	0.010
3	12.0	1.0	1.157	10	--	--	--	--	27	--	--
4	12.0	1.0	1.157	10	--	--	--	--	--	--	--
5	10.5	1.5	1.255	10	985.3	815.7	0.83	--	--	--	--
6	10.5	1.5	1.255	10	1,178.3	1,003.3	0.85	--	--	--	--
7	9.0	2.0	1.370	10	1,308.3	1,013.1	0.77	598	--	0.43	0.014
8	9.0	2.0	1.370	10	1,508.3	1,136.7	0.75	--	--	--	--
9	7.5	2.5	1.509	10	1,668.3	1,195.0	0.72	729	11	0.40	0.016
10	7.5	2.5	1.509	10	--	--	--	--	--	--	--
11	6.0	3.0	1.653	10	--	--	--	--	--	--	--
12	6.0	3.0	1.653	10	1,805.0	880.0	0.49	--	--	--	--
13	4.5	3.5	1.860	10	1,926.7	1,198.3	0.62	--	--	--	--
14	4.5	3.5	1.860	10	2,173.3	1,306.7	0.60	--	--	--	--
15	4.0	3.0	2.125	10	2,035.0	1,158.3	0.57	1455	16	0.59	0.023
16	4.0	3.0	2.125	10	2,870.0	1,488.3	0.52	1455	15	0.46	0.023
17	1.5	4.5	2.480	10	--	--	--	--	--	--	--
18	1.5	4.5	2.480	10	--	--	--	--	--	--	--
19	1.5	4.5	2.480	10	--	--	--	--	--	--	--
20	0.0	5.0	2.976	10	--	--	--	--	--	--	--
23	0.0	5.0	2.976	10	5,126.7	2,136.0	0.42	1716	53	0.27	0.019

Table 7

Priority Pollutant Analytical Data for Acclimation Bioreactor Influents and Effluents

Analyte	Test Day No. 0 Influent	Test Day No. 54 Influent	Test Day No. 54 Effluent	EPA Requested Analysis Test Day No. 112 Effluent 1	EPA Requested Analysis Test Day No. 112 Effluent
Methylene chloride	11.00	5.4	ND	0.0053	0.0039
1,1-dichloroethene	ND*	ND	ND	0.0037	0.0024
cis-1,2-dichloroethene	16.00	19.2	ND	ND	ND
Trans-1,2-dichloroethene	ND	ND	ND	0.060	0.033
Toluene	10.00	ND	ND	ND	ND
Ethylbenzene	ND	1.80 J**	ND	ND	ND
Acetone	ND	23.20 J	ND	ND	ND
2-butanone	260.00	302.00	ND	ND	ND
T-xylene	ND	6.6	ND	0.0065	0.0044
Phenol	0.27	ND	ND	ND	ND
2,4-dimethylphenol	0.63	0.77	ND	ND	ND
Benzoic acid	ND	8.2	ND	ND	ND
2-methylphenol	0.80	0.39	ND	ND	ND
4-methylphenol	0.81	1.3	ND	NE	ND
Diethyl phthalate	ND	0.16	0.014	0.017	0.017
Dibutylphthalate	ND	ND	0.015	ND	ND
Bis(2-ethylhexyl)phthalate	ND	ND	ND	0.012	ND
PPDDT	ND	ND	ND	0.00027	0.000

* Not detected.
** Indicates concentration is below statistical quantitation limits.

Table 8

Activated Sludge Bioreactors Average Operating Parameters

Parameter	Bioreactor No. 1	Bioreactor No. 2	Bioreactor No. 3	Bioreactor No. 4
HRT, day	1.0	1.0	1.0	1.0
SRT, day	2.0	4.0	8.0	16.0
Average DO, mg/ℓ	5.8	5.6	5.7	5.7
pH	8.53	8.55	8.49	8.53
Salinity, %	1.8	1.7	1.7	1.8
Conductivity, μmhos	2,912	2,725	2,829	2,844
SVI	6.6	4.57	5.87	4.04
SS, mg/ℓ	2,649.7	5,260.4	7,390.1	16,769.1
VSS, mg/ℓ	1,196.0	1,831.5	2,439.7	4,609.6
VSS/SS	0.451	0.348	0.330	0.275
F/M ratio*	1.45	0.94	0.71	0.38
Headspace HNU reading, ppm	0.17	0.16	0.19	0.16

* Based on BOD.

Table 9

Average Gross Pollutant Concentrations and Percent Removals in Bioreactors and Control

Parameter	Influent Concentration mg/ℓ	Effluent Concentration mg/ℓ	Percent Removal
Bioreactor No. 1			
BOD	1,729.1	122.2	92.9
COD	3,279.0	1,260.0	61.6
TOC	745.0	302.0	59.5
Bioreactor No. 2			
BOD	1,729.1	130.9	92.4
COD	3,279.0	1,267.0	61.4
TOC	745.0	265.0	64.4
Bioreactor No. 3			
BOD	1,729.1	131.0	92.4
COD	3,279.0	1,567.0	52.2
TOC	745.0	296.0	60.3
Bioreactor No. 4			
BOD	1,729.1	213.7	87.6
COD	3,279.0	1,252.0	61.8
TOC	745.0	271.0	63.6
Control Reactor			
BOD	1,729.1	625.0	63.9
COD	3,279.0	1,820.0	44.5
TOC	745.0	447.0	40.0

Table 10

Priority Pollutant Organic Analysis of the Activated Sludge Bioreactors Influents and Effluents

Analyte	Influents (mg/ℓ)	Effluents				Control (mg/ℓ)
		2 Day (mg/ℓ)	4 Day (mg/ℓ)	8 Day (mg/ℓ)	16 Day (mg/ℓ)	
		1st Sampling				
Phenol	1.57	ND*	ND	ND	ND	0.1400 J
2,4-dimethylphenol	1.20	ND	ND	0.0217 J**	ND	0.3670 J
2-methylphenol	2.61	ND	ND	0.0105 J	0.0112 J	0.6140
4-methylphenol	5.75	0.17600	0.1510	0.1730	0.0287 J	0.9500
Isophorone	0.023 J	ND	ND	0.0128 J	ND	0.0447 J
Bis(2-Ethylhexyl)phthalate	ND	ND	ND	0.0277 J	ND	ND
Vinyl chloride	4.50	ND	ND	ND	ND	ND
Methylene chloride	1.30	0.0046 J	0.0045 J	ND	ND	ND
cis-1,2-dichloroethene	12.20	0.0032 J	0.0094	0.0250	0.0069	ND
Toluene	9.00	ND	ND	0.0069	ND	ND
Ethylbenzene	0.43 J	ND	ND	0.0013 J	ND	ND
Acetone	16.30	ND	ND	1.0500	ND	ND
2-butanone	296.00	ND	ND	0.1500	ND	ND
4-methyl-2-pentanone	25.00	ND	ND	0.0540	0.0150 J	61.0000
T-xylene	1.70	ND	ND	0.0062	ND	ND
		2nd Sampling				
Phenol	1.57	ND	0.0030 J	0.0014 J	0.0193 J	NA†
2,4-dimethylphenol	1.20	ND	ND	ND	0.0070 J	NA
2-methylphenol	2.61	0.0153 J	0.0274 J	0.1550	0.5520	NA
4-methylphenol	5.75	ND	ND	ND	ND	NA
Isophorone	0.023 J	ND	ND	ND	ND	NA
Bis(2-Ethylhexyl)phthalate	ND	0.0160 J	ND	ND	ND	NA
Vinyl chloride	4.50	ND	ND	ND	ND	NA
Methylene chloride	1.30	0.0043 J	ND	0.0055	ND	NA
cis-1,2-dichloroethene	12.20	0.0150	0.0180	0.0180	0.0240	NA
Toluene	9.00	ND	ND	ND	ND	NA
Ethylbenzene	0.43 J	ND	ND	ND	ND	NA
Acetone	16.30	ND	ND	ND	ND	NA
2-butanone	296.00	ND	ND	ND	ND	NA
4-methyl-2-pentanone	25.00	ND	ND	ND	ND	NA
T-xylene	1.70	ND	ND	0.0042 J	0.0030 J	NA

* Not detected.
** Indicates concentration is below statistical quantitation limits.
† Not analyzed due to biological growth in reactor.

Table 11

Analytical Data on Waste Sludge from AS Bioreactors

Analyte	Concentration mg/kg
Methylene chloride	4.4
Acetone	18.2
2-butanone	16.2
Phenol	0.71 J*
Phenanthrene	0.53 J
Dibutylphthalate	0.12 J
Fluoranthene	0.85 J
Pyrene	1.2 J
Chrysene	0.49 J
Benzo(a)anthracene	0.40 J
Bis(2-ethylhexyl)phthalate	5.5
Benzo(b)fluoranthene	0.42 J
Benzo(k)fluoranthene	0.31 J

* Indicates value is below statistical quantitation limits.

Table 12

Activated Sludge Biokinetic Constants

Constant	BOD mg/mg	r^2	COD mg/ℓ	r^2	TOC	r^2
Y, mg/mg	0.3446	0.7	0.26	0.7	1.21	0.7
k_d, days	0.0055	0.7	0.039	0.7	0.057	0.7
K_s, mg/ℓ	18.3	0.1	237.9	0.0	NC*	NC
u_m, hr	0.24	0.1	0.225	0.0	NC	NC

Note: r^2 - correlation of fit.
* Not calculated due to inappropriate data.

Table 13

TVOC Air Stripping Data

Time min	C/C_o	W/W_o	Ft
	Run 1		
0	1	1	1
7	0.993	0.994	0.987
14	0.724	0.988	0.716
21	0.632	0.983	0.621
28	0.599	0.977	0.584
35	0.633	0.971	0.614
42	0.496	0.965	0.479
49	0.373	0.959	0.358
56	0.293	0.953	0.279
63	0.119	0.947	0.112

Estimated K_s/a = 34.7

Time min	C/C_o	W/W_o	Ft
	Run 2		
0	1	1	1
7	0.681	0.994	0.677
14	0.575	0.988	0.569
21	0.476	0.983	0.468
28	0.501	0.977	0.489
35	0.379	0.971	0.368
42	0.279	0.965	0.269
49	0.239	0.959	0.229
56	0.209	0.953	0.199
63	0.181	0.947	0.171

Estimated K_s/a = 67.1

Table 14

Activated Carbon Adsorption Equilibrium Batch Data

Analyte	Carbon Dose g/ℓ	Influent C mg/ℓ	Final C mg/ℓ	X/M mg/g
Acetone	1	19	18.0	0.8
	5	19	13.0	1.0
	20	19	3.8	0.6
	40	19	1.7	0.4
	100	19	2.0	0.1
2-butanone	1	280	80.0	167.6
	5	280	72.0	34.8
	20	280	16.0	11.1
	40	280	1.5	5.8
	100	280	2.2	2.3
Total VOCs	1	363.8	124.8	200.3
	5	363.8	87.2	46.3
	20	363.8	19.8	14.4
	40	363.8	3.2	7.5
	100	363.8	4.2	3.0
Total BNAs	1	12.3	1.7750	8.8
	5	12.3	0.0009	2.1
	20	12.3	0.0004	0.5
	40	12.3	0	0.3
	100	12.3	0	0.1
TOC	1	363.8	124.8	200.3
	5	363.8	87.2	46.3
	20	363.8	19.8	14.4
	40	363.8	3.2	7.5
	100	363.8	4.2	3.0
COD	1	3,870	2,350	1,274.
	5	3,870	2,130	291.2
	20	3,870	1,250	109.8
	40	3,870	1,060	58.3
	100	3,870	760	26.0

Table 15

Activated Carbon Equilibrium Batch Fruendlich Model Constants

Analyte	K mg/g	n	r^2
Acetone	0.1628	1.583	0.66
2-butanone	2.085	1.263	0.80
Total VOCs	1.339	1.111	0.89
Total BNAs	7.965	3.565	0.98
TOC	1.91EE-12	0.196	0.87
COD	4.24EE-8	0.330	0.88

Note: r^2 = correlation of fit.

Table 16

Activated Carbon Adsorptive Capacity Estimations Using Fruendlich Model

Analyte	K mg/g	n	C mg/ℓ	X/M mg/g
Acetone	0.1628	1.583	18	1.0107
			10	0.6972
			1	0.1628
			0.01	0.0089
			0.001	0.0021
2-butanone	2.085	1.263	500	285.7971
			50	46.1628
			5	7.4564
			0.5	1.2044
			0.05	0.1945
			0.005	0.0314
Total VOCs	1.339	1.111	500	359.8293
			50	45.2904
			5	5.7005
			0.05	0.0903
			0.005	0.0114
Total BNAs	7.965	3.565	10	15.1946
			1	7.9650
			0.1	4.1752
			0.01	2.1886
			0.001	1.1473
TOC	1.9E-12	0.196	1,000	3.87E+03
			100	3.06E-02
			10	2.42E-07
			1	1.91E-12
			0.1	1.51E-17
COD	4.24E-08	0.330	5,000	6.86E+03
			500	6.40E+00
			50	5.97E-03
			5	5.56E-06
			0.5	5.19E-09

Table 17

PAC/AS Bioreactors Average Operating Parameters

Parameter	Bioreactor No. 1	Bioreactor No. 2	Bioreactor No. 3	Bioreactor No. 4	Control
HRT, day	1.0	1.0	1.0	1.0	1
SRT, day	8.0	8.0	8.0	8.0	8
DO, mg/ℓ	7.3	6.5	7.1	7.3	5.7
pH	8.44	8.27	8.25	8.34	8.49
Salinity, %	1.8	1.7	1.8	1.9	1.7
Conductivity, μmhos	2,776	2,837	2,743	2,933	2,829
SVI	17	19	20	26	5.87
PACSS, mg/ℓ	1,000	2,000	5,000	8,000	0
TSS, mg/ℓ	11,438	10,663	20,399	26,033	--
SS mg/ℓ	10,438	8,663	15,399	18,033	7,390
VSS mg/ℓ	4,394.0	4,514	10,162	14,228	1,831
VSS/SS	0.421	0.521	0.660	0.789	0.330
F/M ratio*	0.37	0.36	0.16	0.11	0.71
Headspace HNU readings, ppm	0.6	0.5	0.4	0.4	

* Based on BOD.

Table 18

PAC/AS Bioreactors, Priority Pollutant Influents and Effluents Analyses

| Analyte | Influent | Effluents | | | | Control |
		1,000 mg/ℓ PAC Dose	2,000 mg/ℓ PAC Dose	4,000 mg/ℓ PAC Dose	8,000 mg/ℓ PAC Dose	
Phenol	0.86	0.0012 J*	0.0053 J	0.0035 J	ND**	0.0028 J
2,4-dimethylphenol	1.65	0.0005 J	0.008 J	0.0017 J	ND	ND
2,4-dichlorophenol	0.085 J	ND	ND	ND	ND	ND
Benzoic acid	5.68	0.003 J	0.0055 J	0.007 J	ND	0.0088 J
2-methylphenol	1.87	ND	ND	ND	ND	ND
4-methylphenol	6.07	0.0027 J	ND	ND	ND	ND
Isophorone	0.040 J	0.012	0.013	0.011	ND	0.021
Butylbenzylphthalate	ND	ND	ND	ND	0.0087 J	ND
Bis(2-ethylhexyl)phthalate	ND	0.013	0.0095 J	0.016	0.0073 J	0.0079 J
Di-N-octylphthalate	ND	ND	ND	ND	0.0091 J	ND
Methylene chloride	1.3	0.0109	ND	0.104	0.0738	0.0632
cis-1,2-dichloroethene	12.2	0.0172	0.0211	ND	ND	ND
2-butanone	296.0	ND	ND	0.0226 J	0.329	ND

*   Indicates concentration is below quantitation limits.
** Not detected.

Table 19

Average Gross Pollutant Concentrations and Percent
Removals in PAC/AS Bioreactors and Control

Parameter	Influent Concentration mg/ℓ	Effluent Concentration mg/ℓ	Percent Removal
PAC/AS Bioreactor No. 1			
BOD	1,611.2	80.2	95.0
COD	3,695	1,029.0	72.2
TOC	775	297.6	61.6
PAC/AS Bioreactor No. 2			
BOD	1,611.2	127.7	92.1
COD	3,695	1,063.0	71.2
TOC	775	281.7	63.7
PAC/AS Bioreactor No. 3			
BOD	1,611.2	53.2	96.7
COD	3,695	673.0	81.8
TOC	775	175.9	77.3
PAC/AS Bioreactor No. 4			
BOD	1,611.2	36.9	97.7
COD	3,695	490.0	86.7
TOC	775	145.0	81.3
Control Reactor			
BOD	1,729.1	131.0	92.4
COD	3,279.0	1,567.0	52.2
TOC	745.0	296.0	60.3
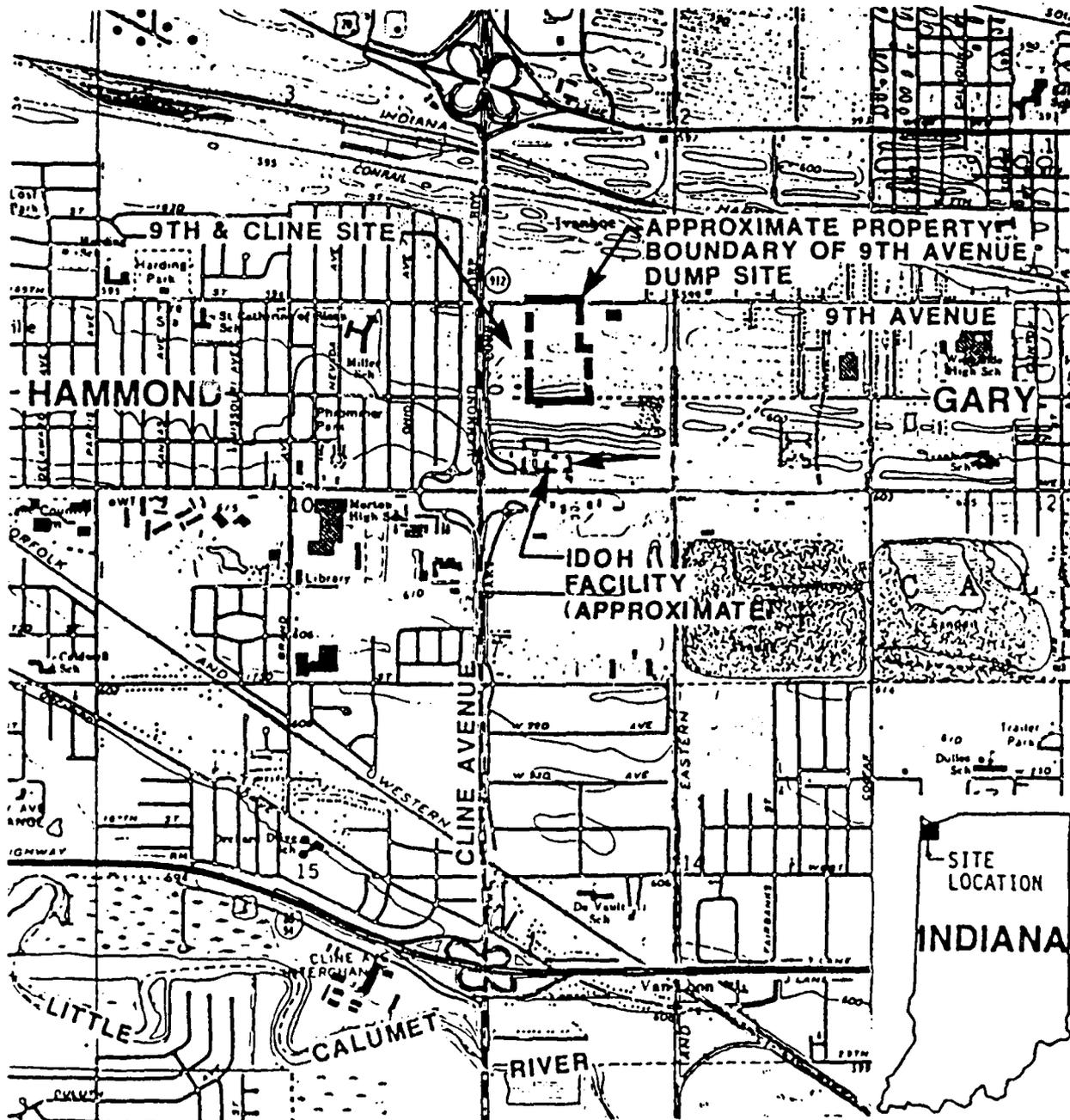
Figure 1. Site location map
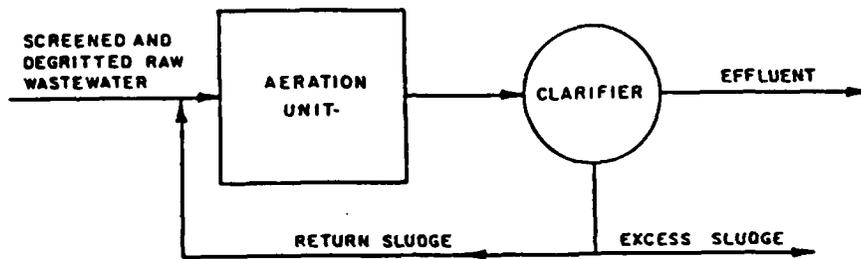
Figure 2.   Activated sludge treatment system

TWO-VESSEL GRANULAR CARBON ADSORPTION SYSTEM
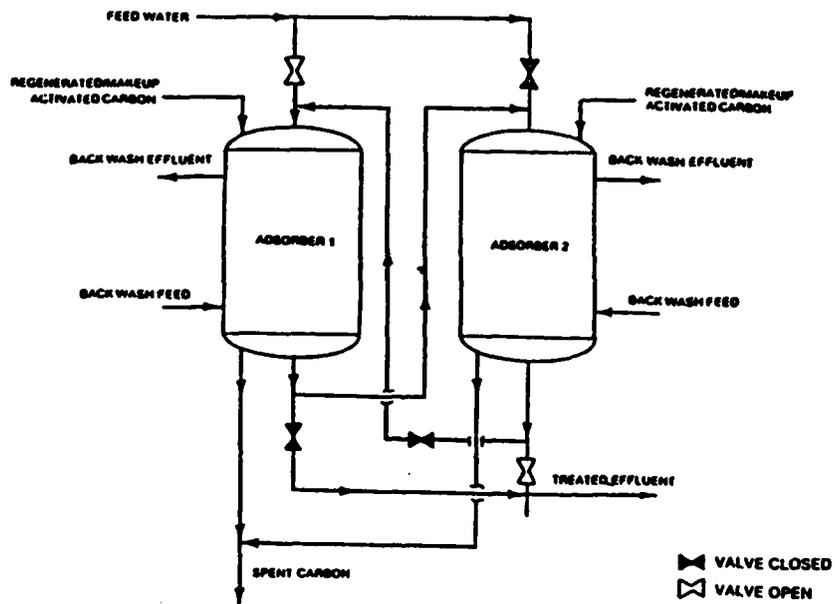
Figure 3.   Activated carbon treatment system
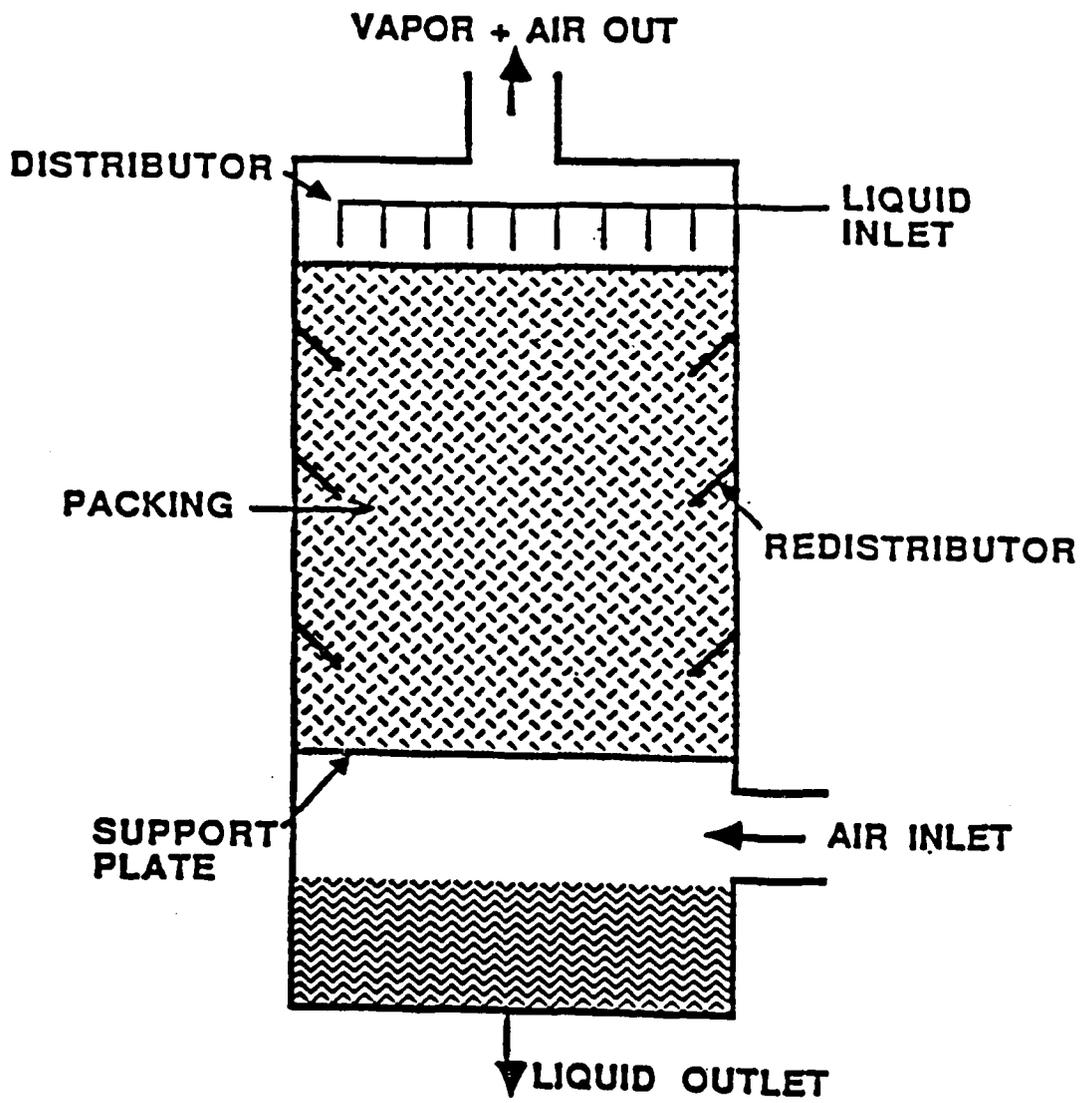
Figure 4. Schematic diagram of a countercurrent
air-water stripper
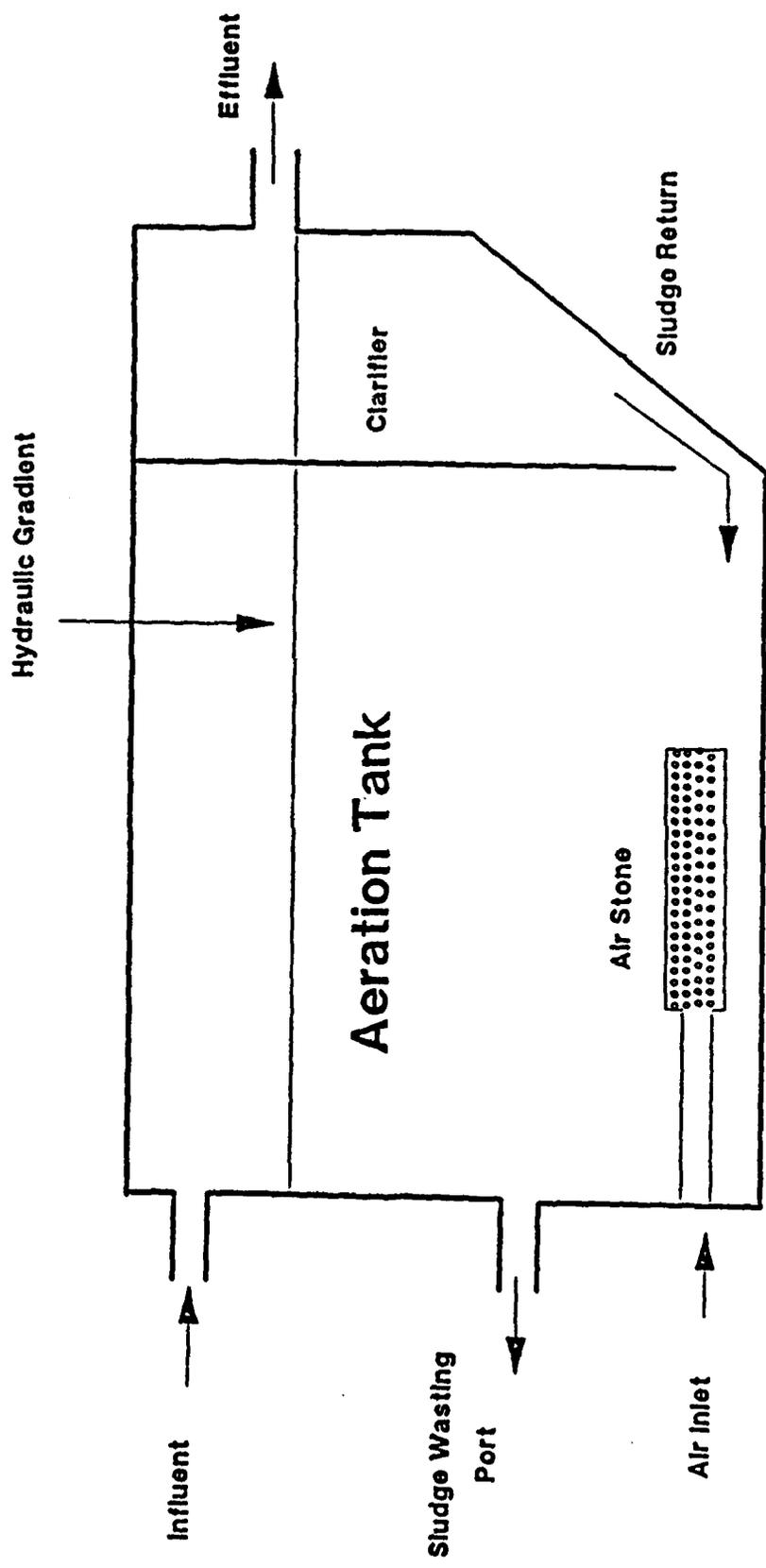
Figure 5. Activated sludge bioreactor

BONDED FOAM LINER
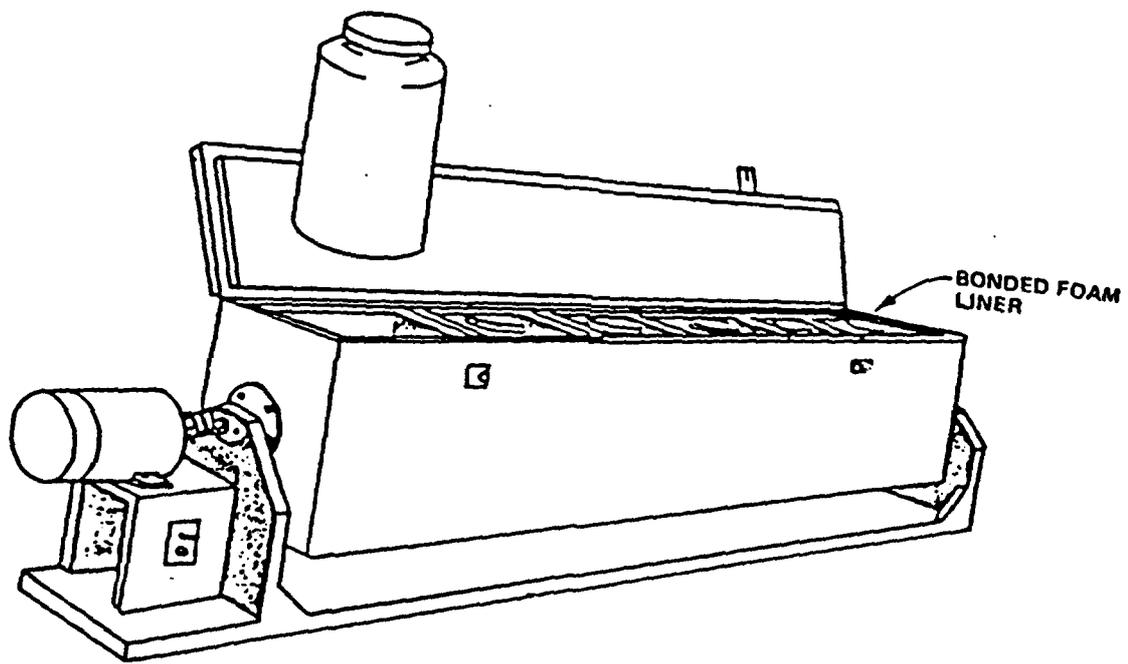
Figure 6.   Rotary tumbler
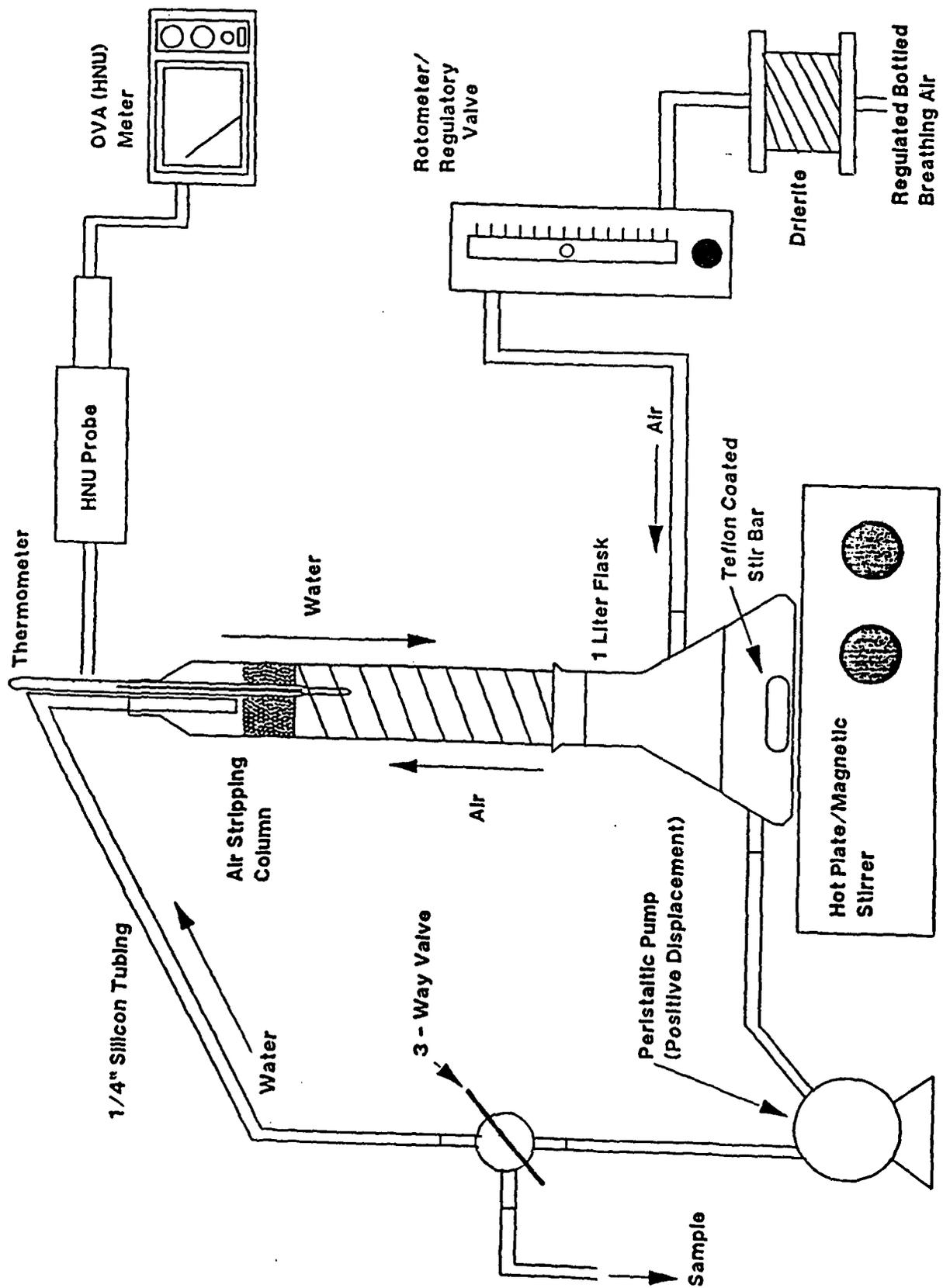
Figure 7. Bench-scale air stripping unit
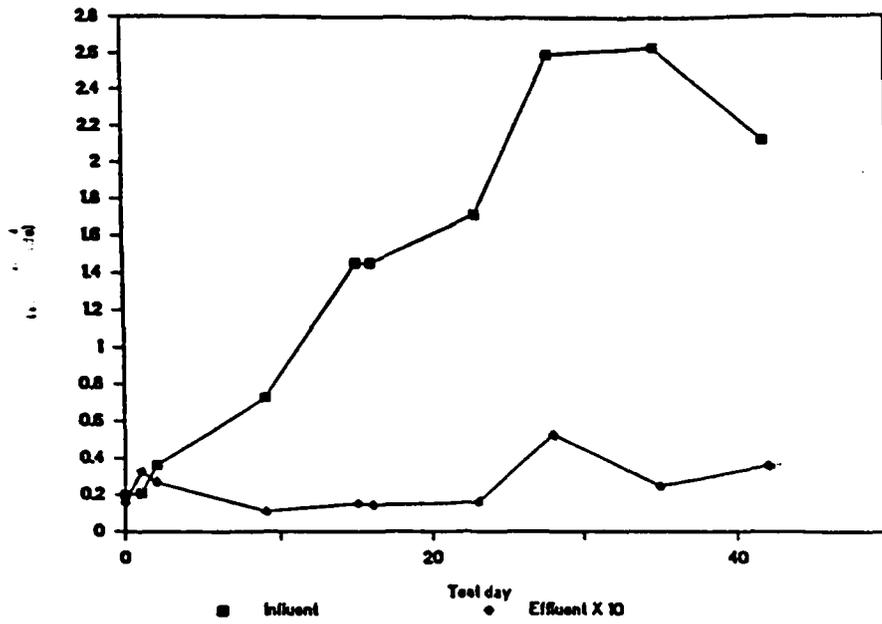
Figure 8. Acclimation bioreactor influent and effluent
BOD concentrations versus test time
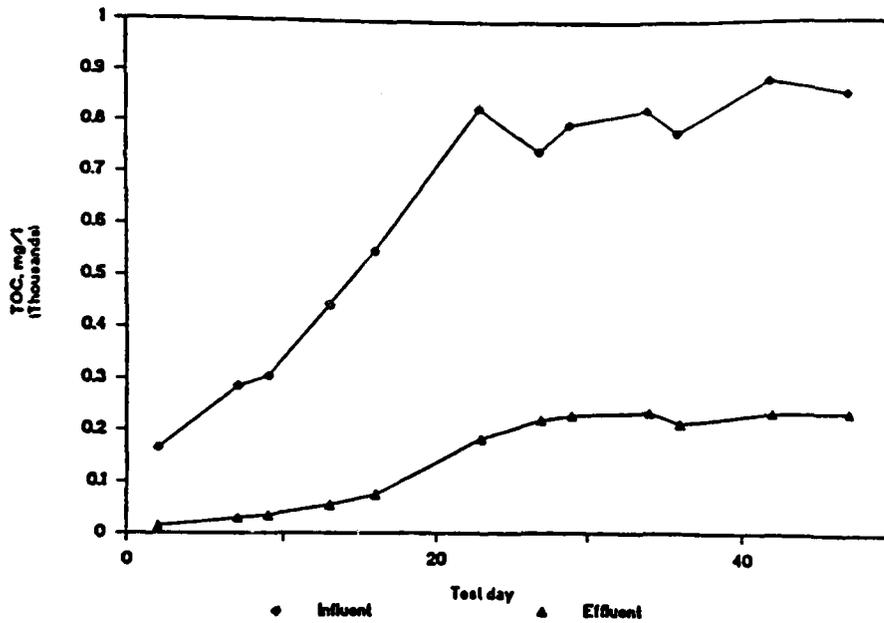
Figure 9. Acclimation bioreactor influent and effluent
TOC concentrations versus test time
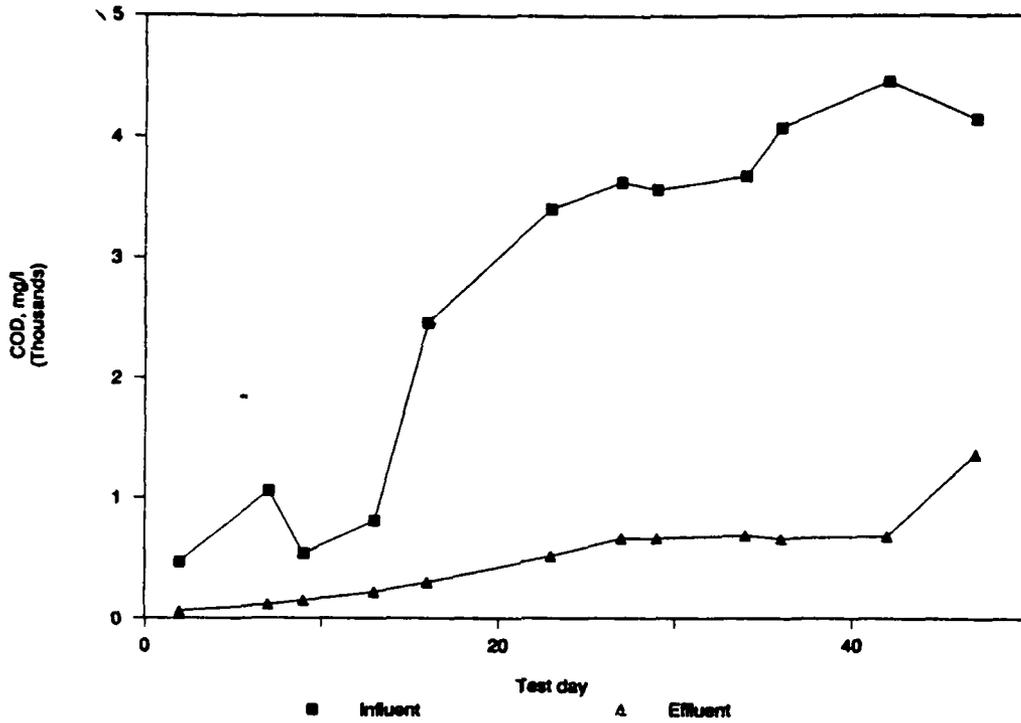
Figure 10.   Acclimation bioreactor influent and effluent
COD concentrations versus test time
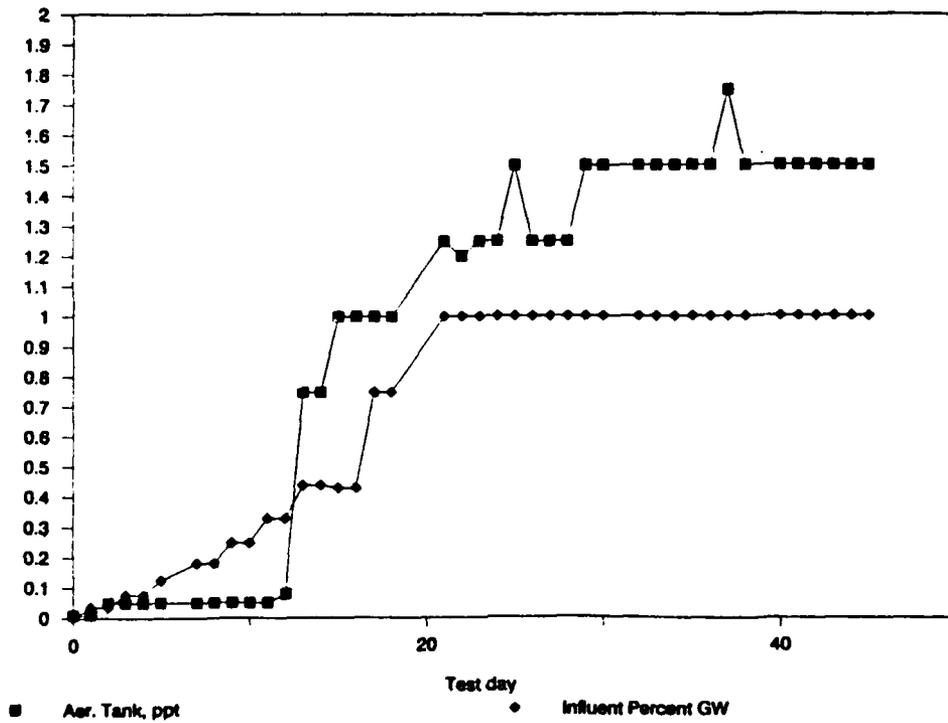
Figure 11.   Acclimation bioreactor mixed liquor salinity
concentrations and influent groundwater-to-wastewater
ratios
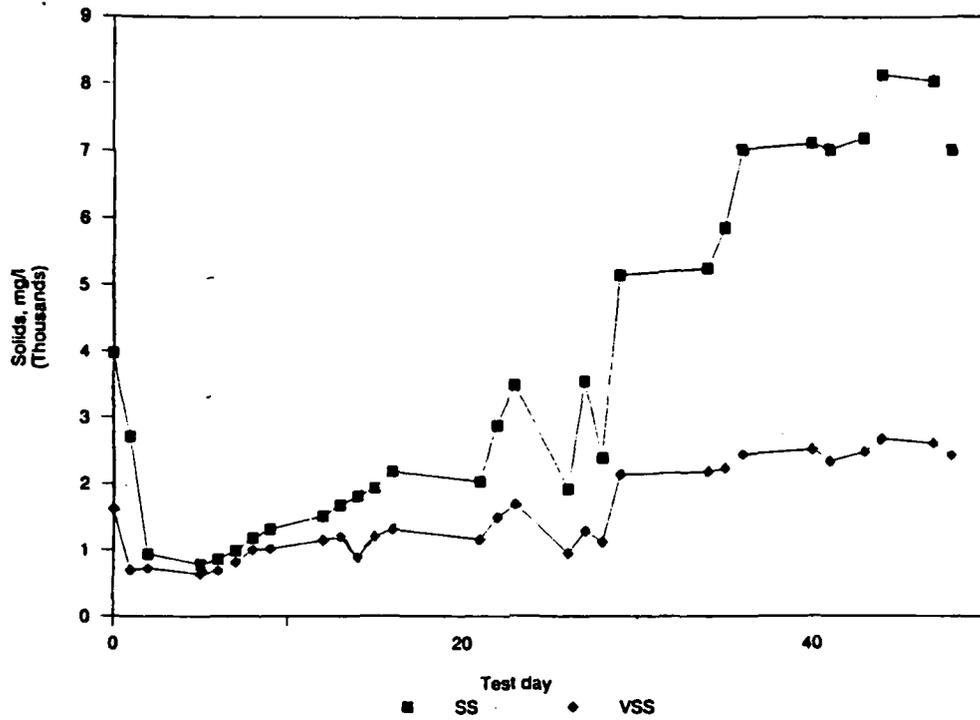
Figure 12.   Acclimation bioreactor mixed liquor SS and
VSS concentrations versus test time
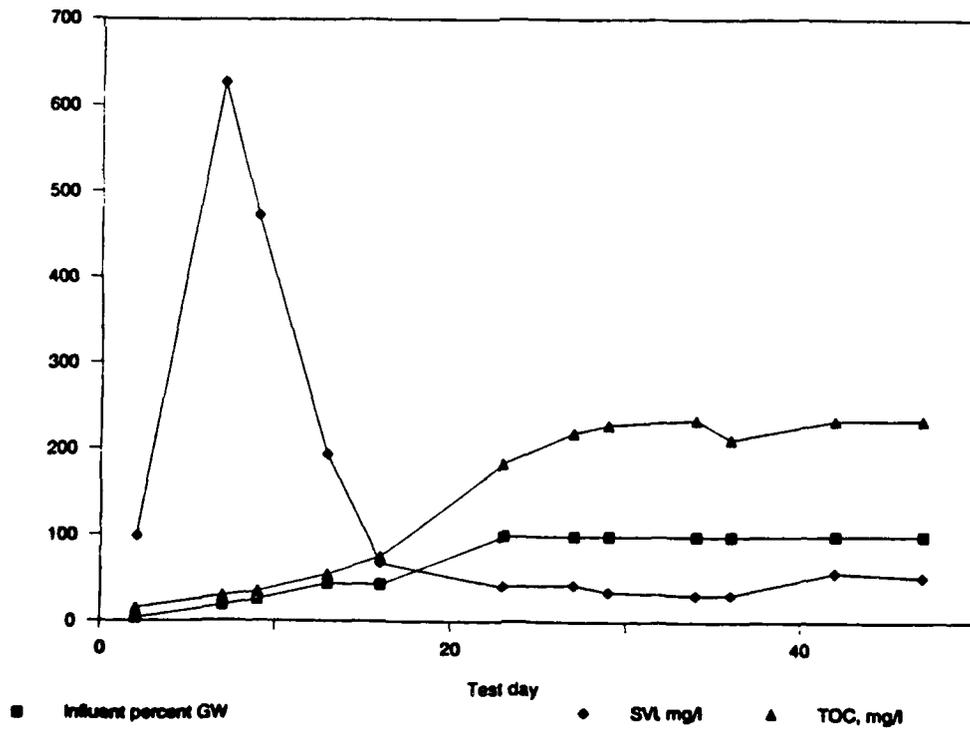
Figure 13.   Ratio of groundwater sample to wastewater
in the acclimation bioreactor influent, SVI, and effluent
TOC concentrations versus test time
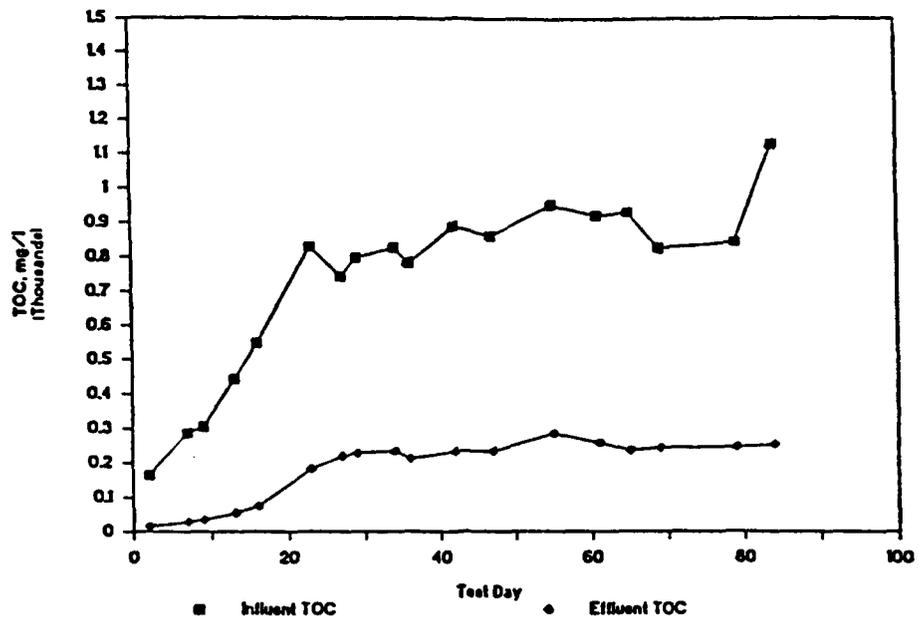
Figure 14. Acclimation bioreactor influent and effluent
TOC concentrations versus test time
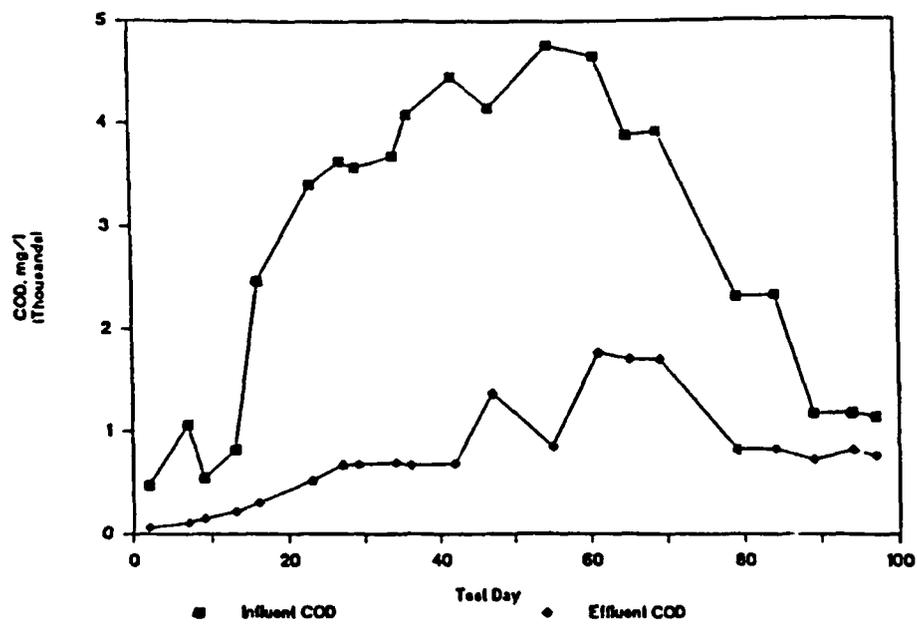
Figure 15. Acclimation bioreactor influent and effluent
COD concentrations versus test time
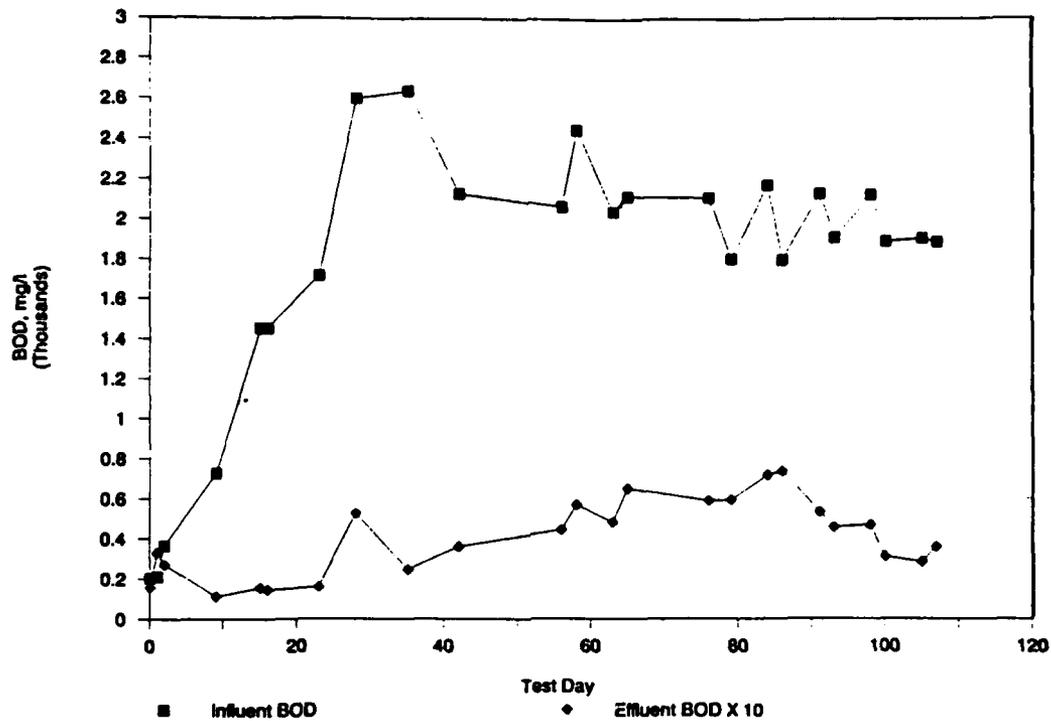
Figure 16. Acclimation bioreactor influent and effluent
BOD concentrations versus test time
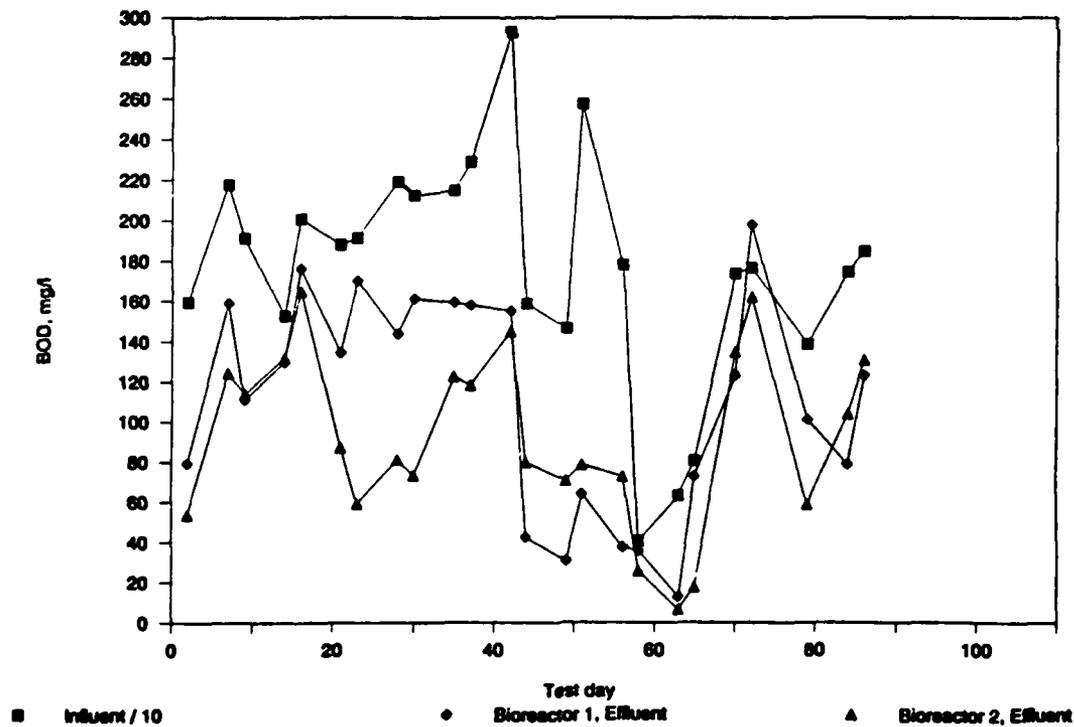
Figure 17. Activated sludge bioreactors Nos. 1 and 2 influents and
effluents versus test day during the transitional phase
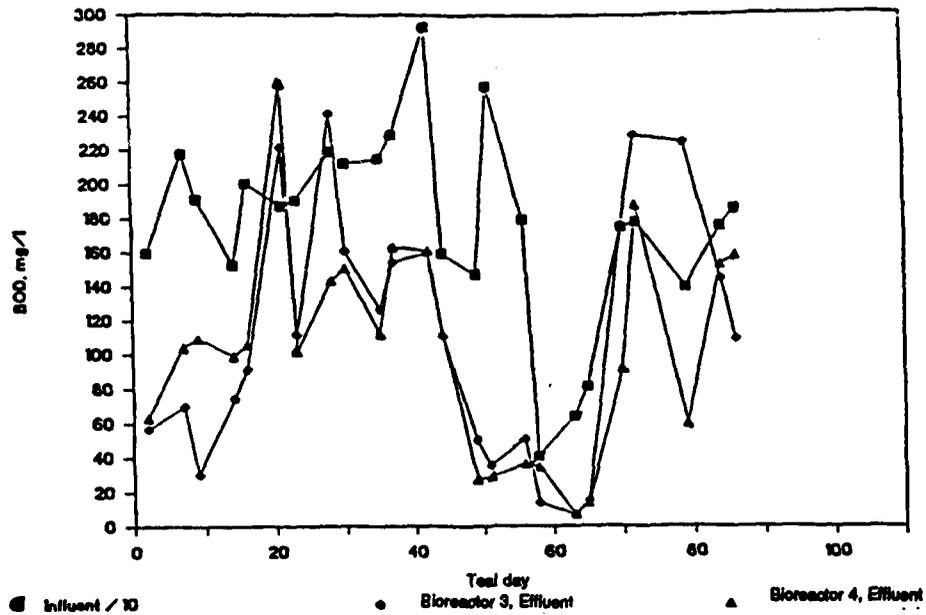
Figure 18. Activated sludge bioreactors Nos. 3 and 4 influents and
effluents versus test day during the transitional phase
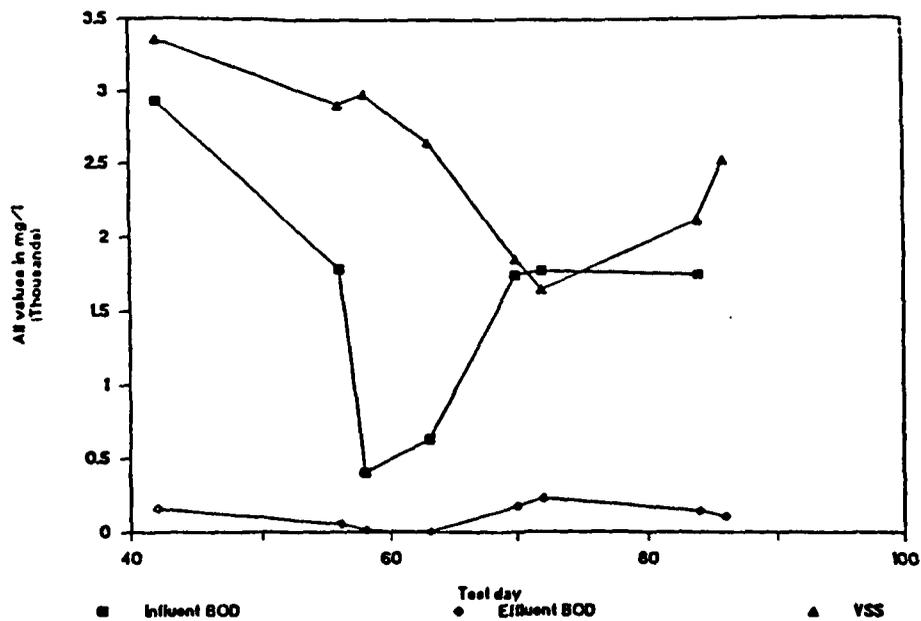
Figure 19. Transition AS bioreactors influent and effluent
BOD concentrations and mixed liquor VSS versus test time
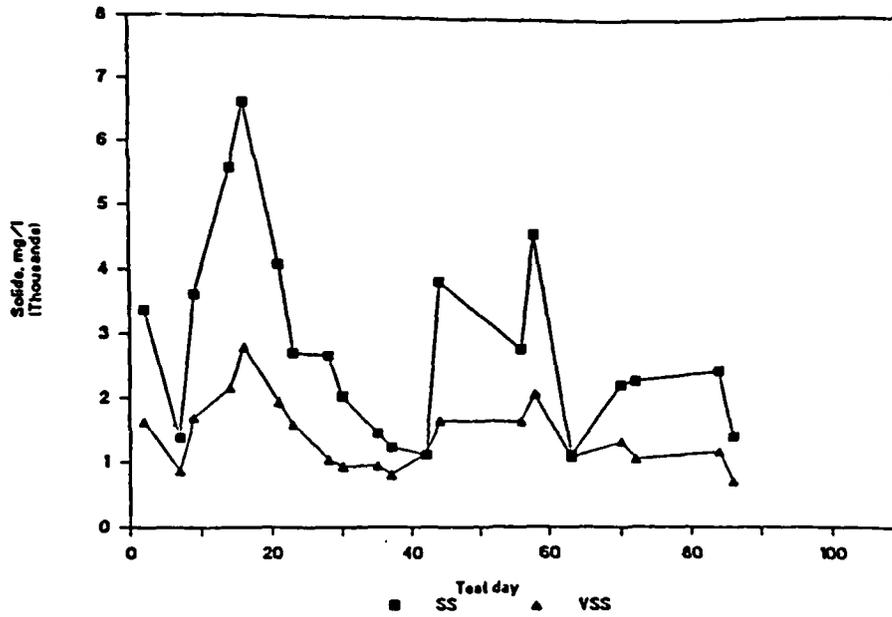
Figure 20. Transitional AS bioreactor No. 1 mixed
liquor solids data versus test time
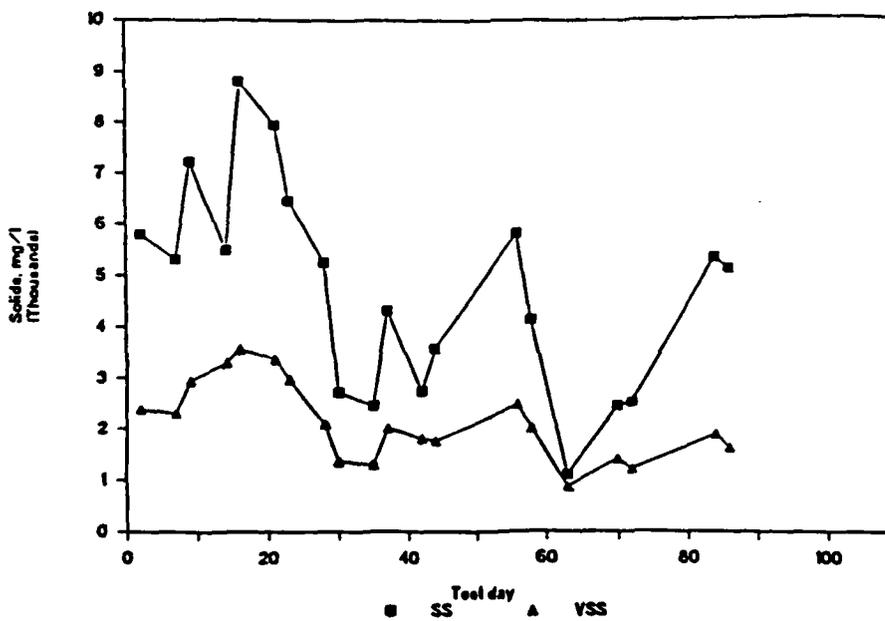
Figure 21. Transitional AS bioreactor No. 2 mixed
liquor solids data versus test time
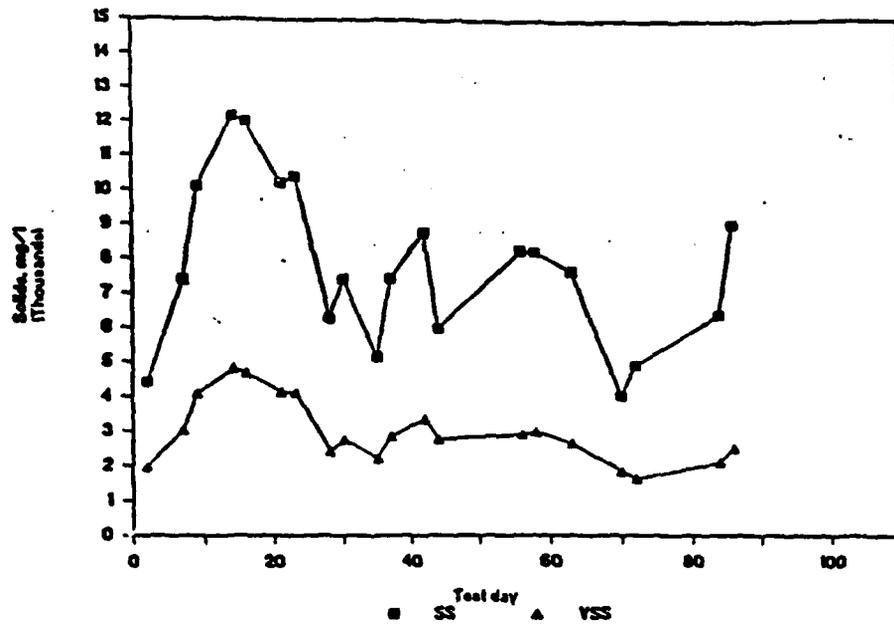
Figure 22.   Transitional AS bioreactor No. 3 mixed
liquor solids data versus test time
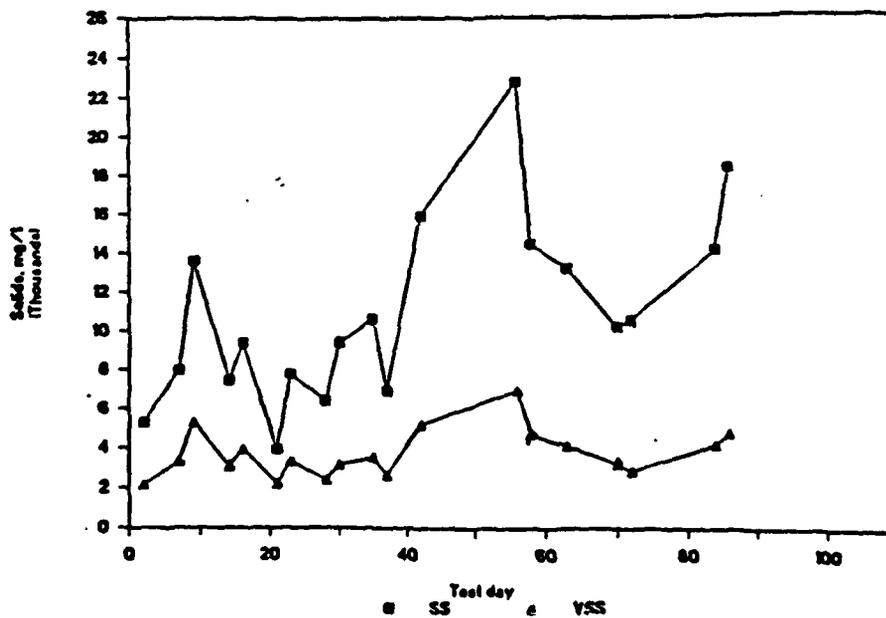
Figure 23.   Transitional AS bioreactor No. 4 mixed
liquor solids data versus test time
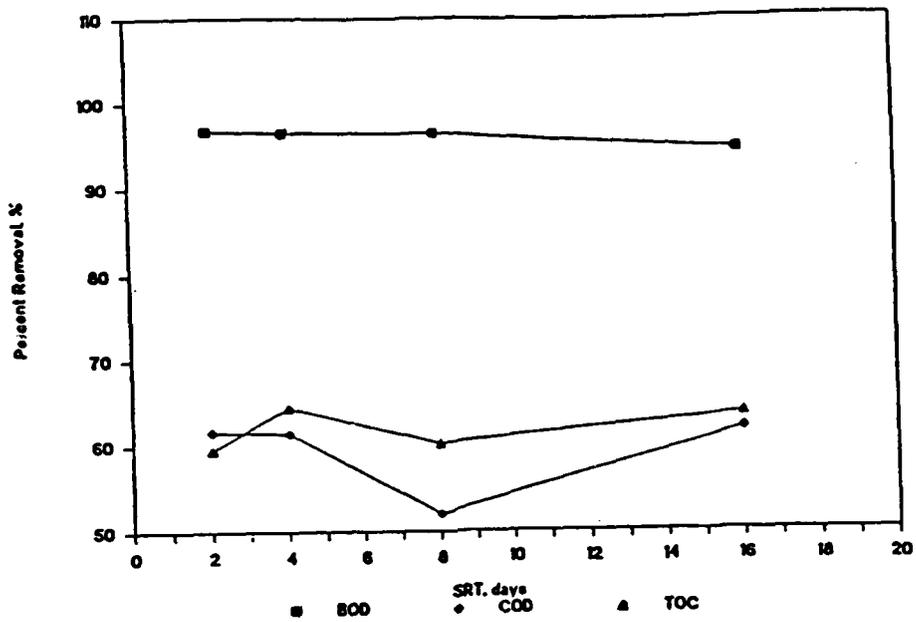
Figure 24. Activated sludge bioreactors gross pollutant percent removals
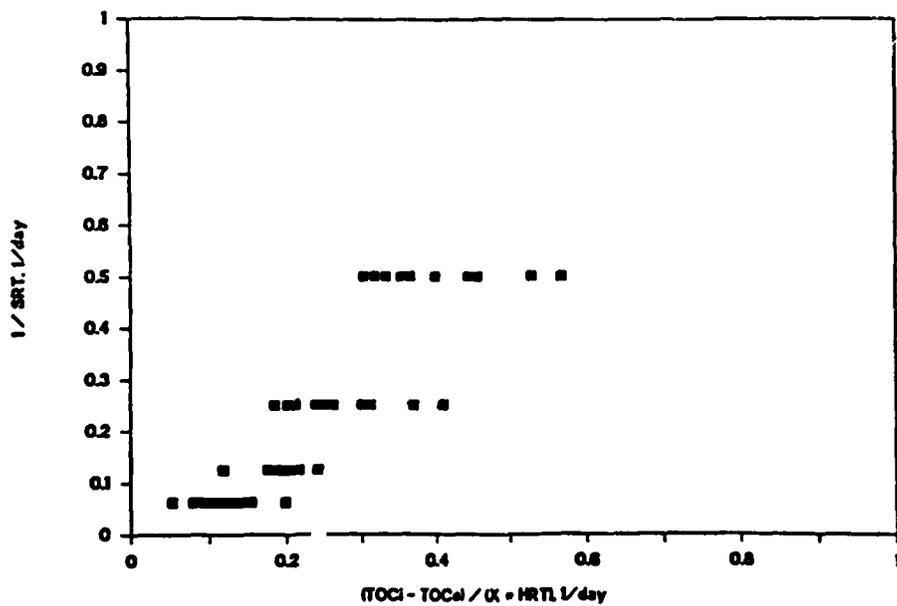
Figure 25. Determination of Y and k_d using TOC
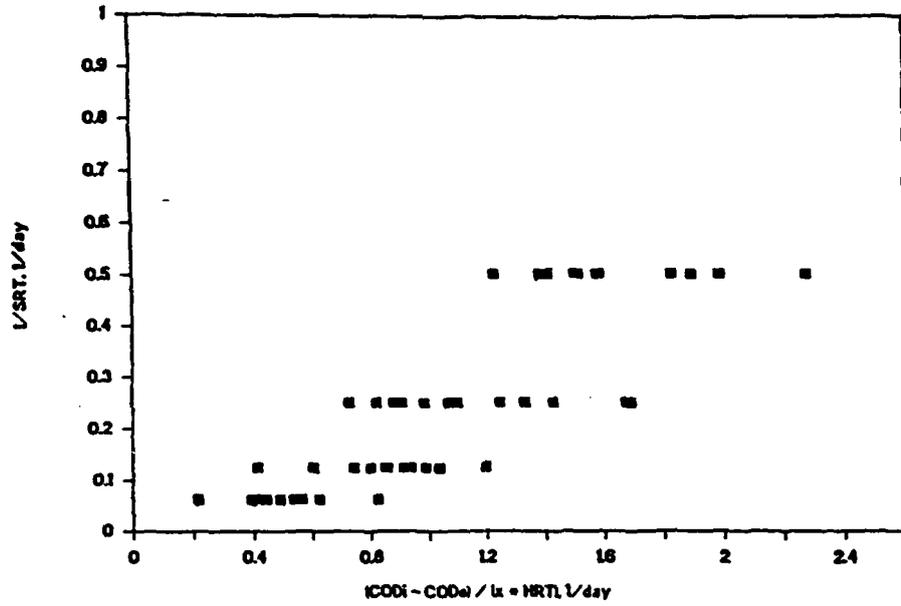
Figure 26. Determination of Y and k_d using COD
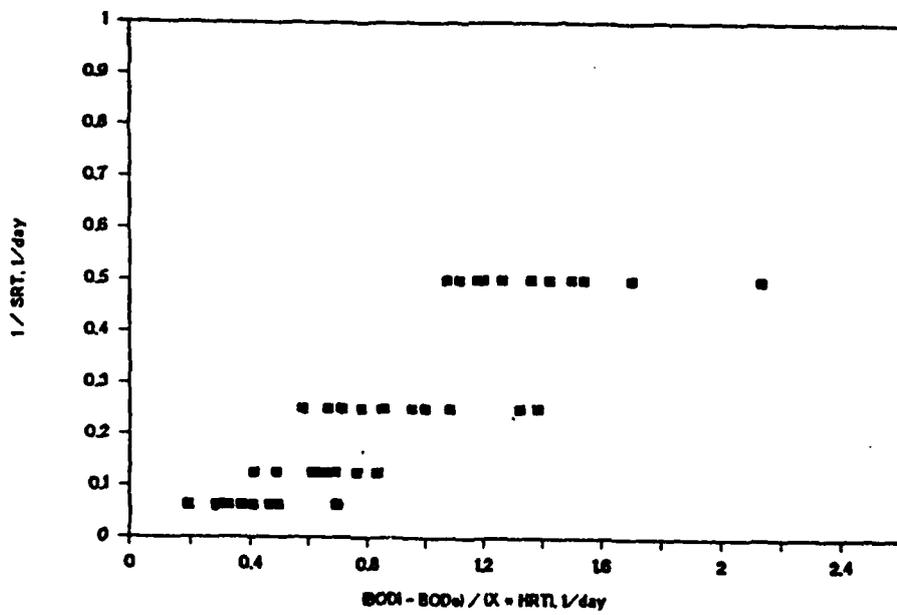
Figure 27. Determination of Y and k_d using BOD
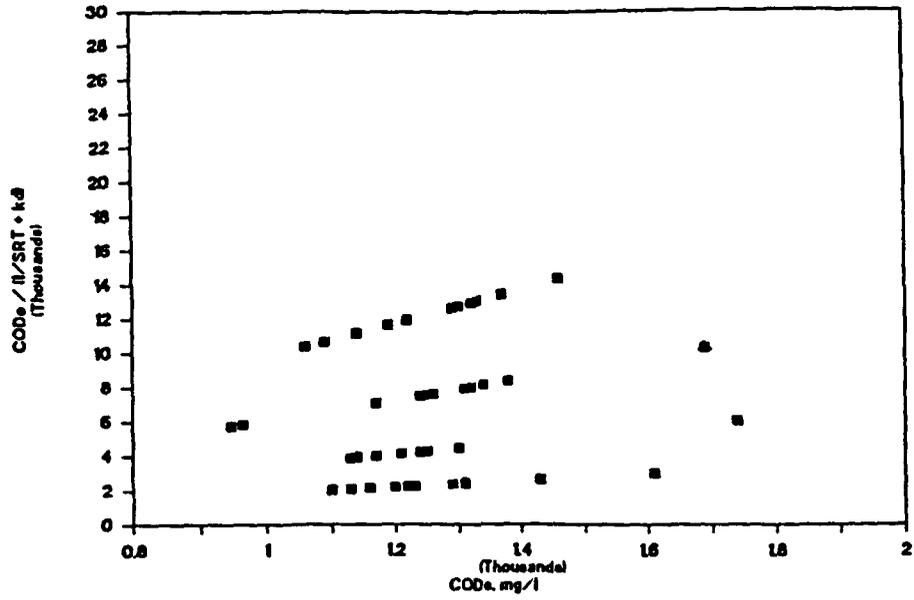
Figure 28. Determination of K_s and u_m using COD
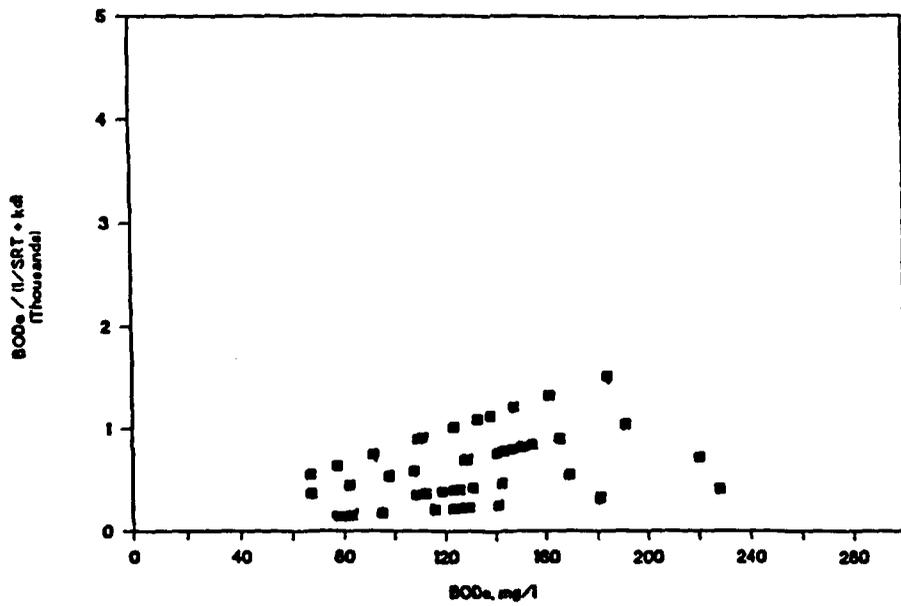
Figure 29. Determination of K_s and u_m using BOD
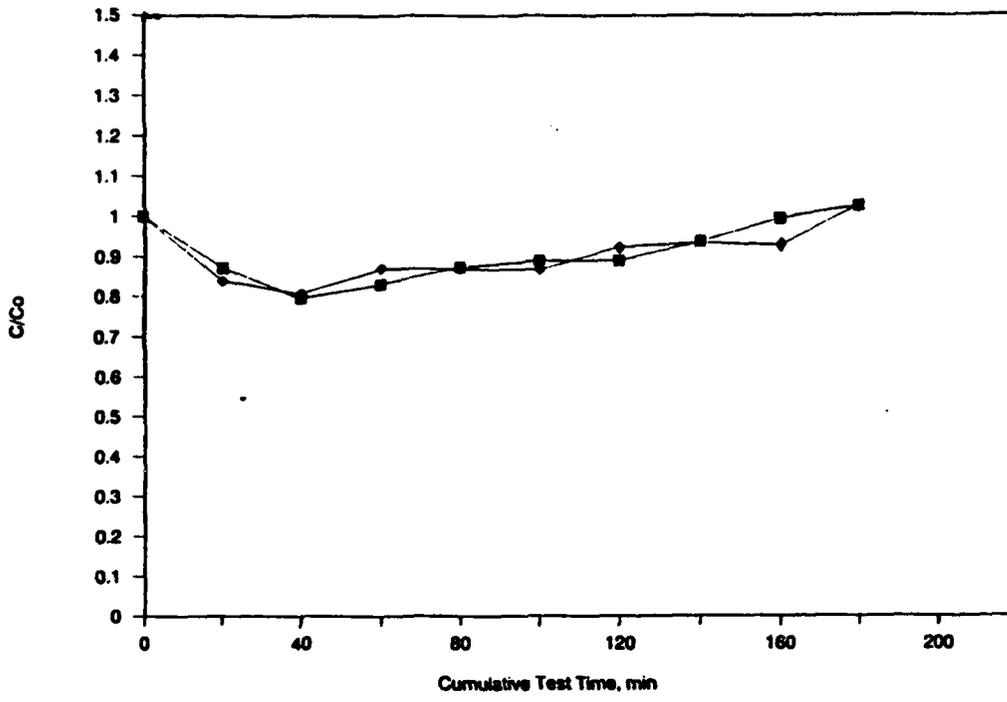
Figure 30. Air stripping TOC data
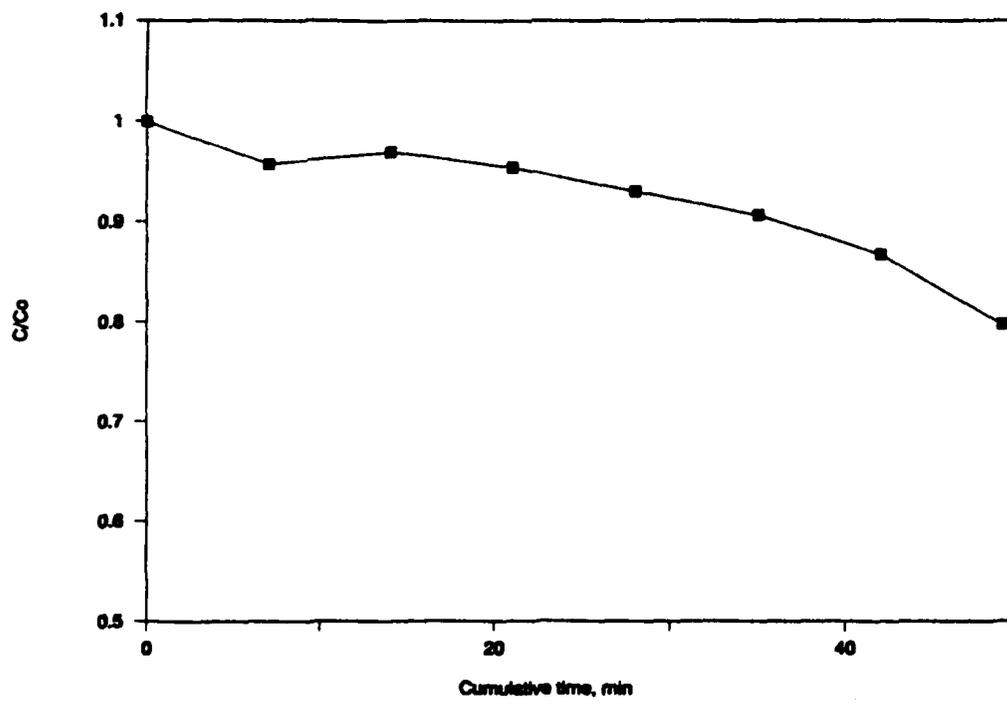
Figure 31. Air stripping COD data
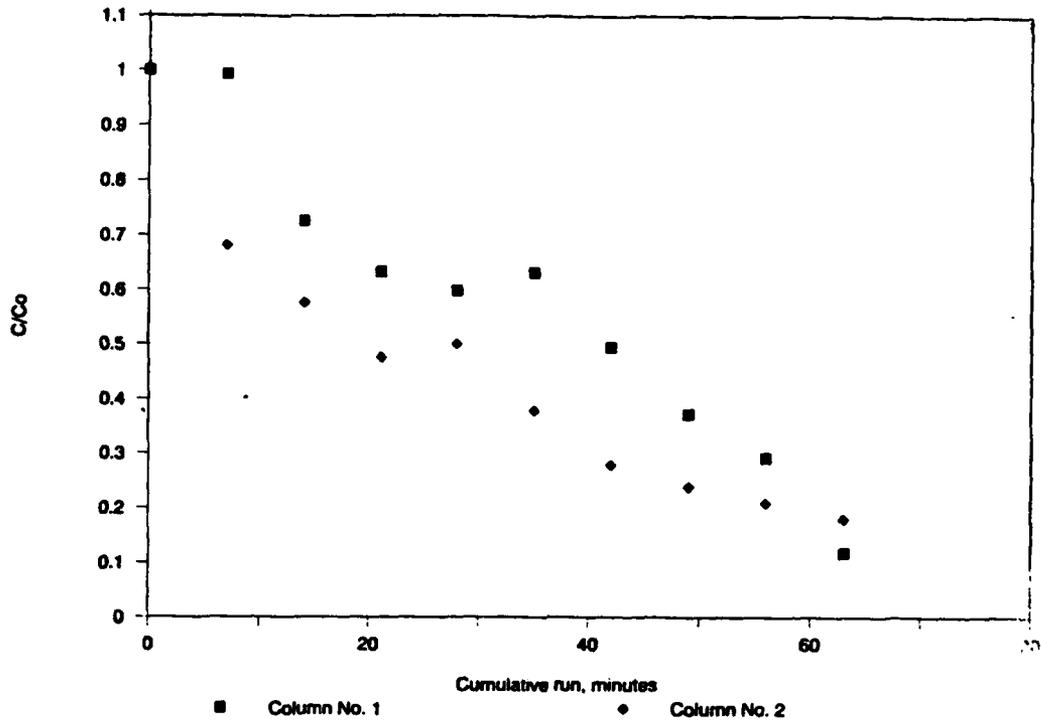
Figure 32. Air stripping TVOC data
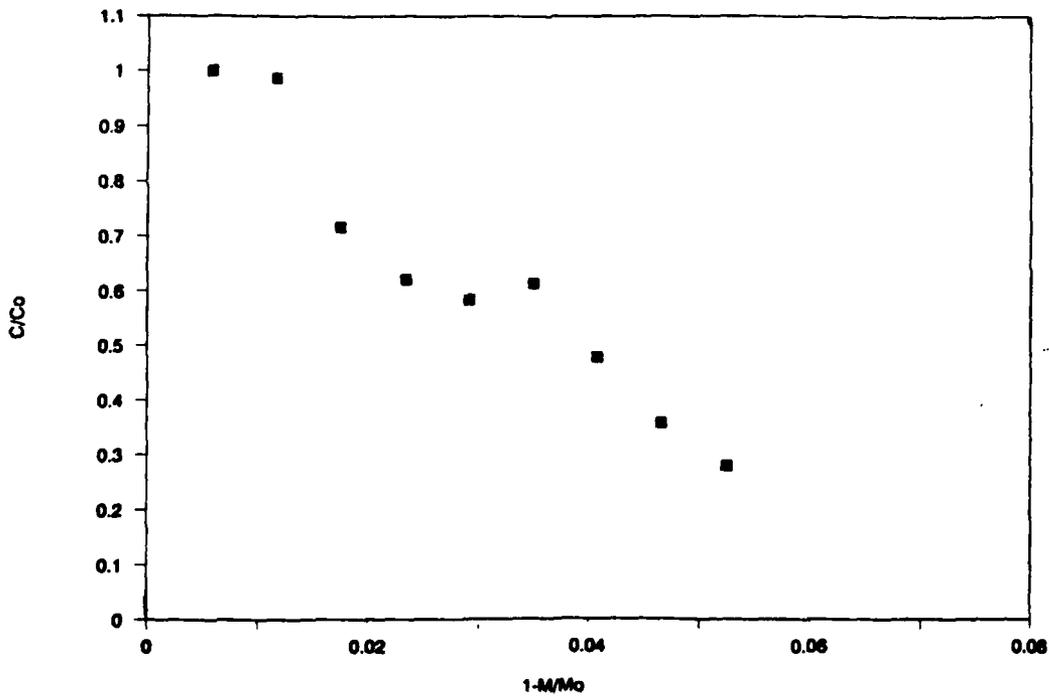
Figure 33. Air stripping TVOC F data
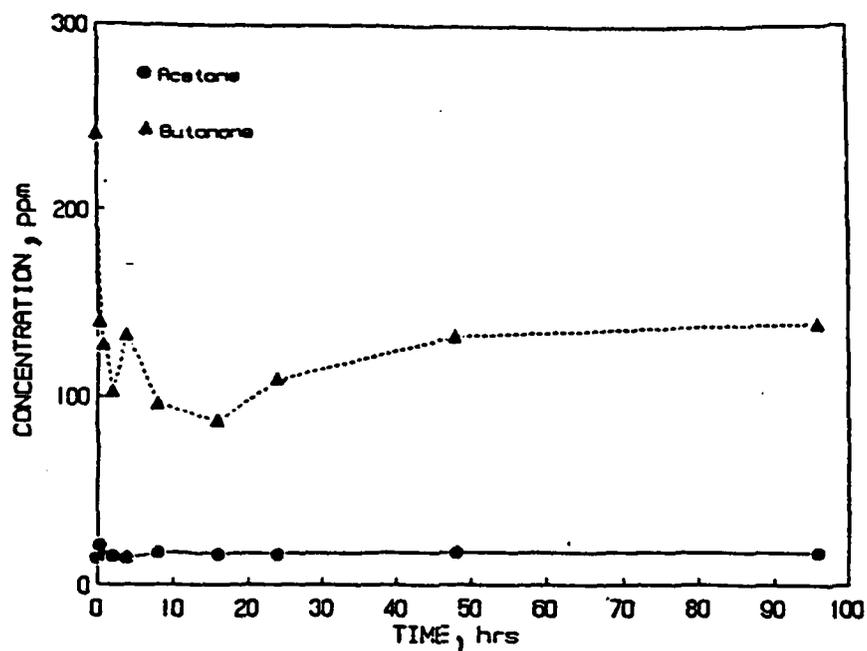
Figure 34. Acetone and 2-butanone activated carbon
adsorption equilibrium data
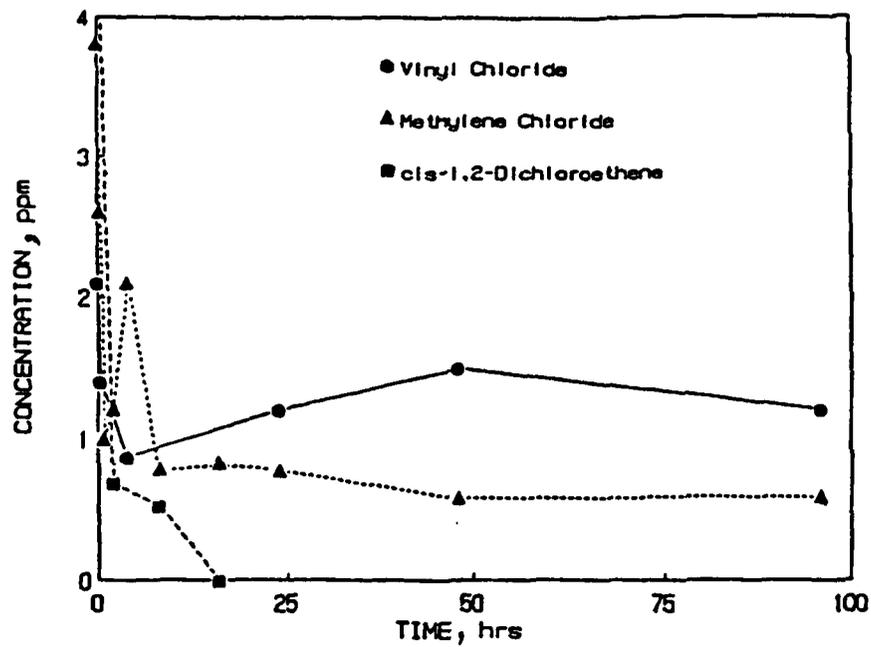
Figure 35. Vinyl chloride, methylene chloride, and
cis-1,2-dichloroethene AC adsorption equilibrium
data
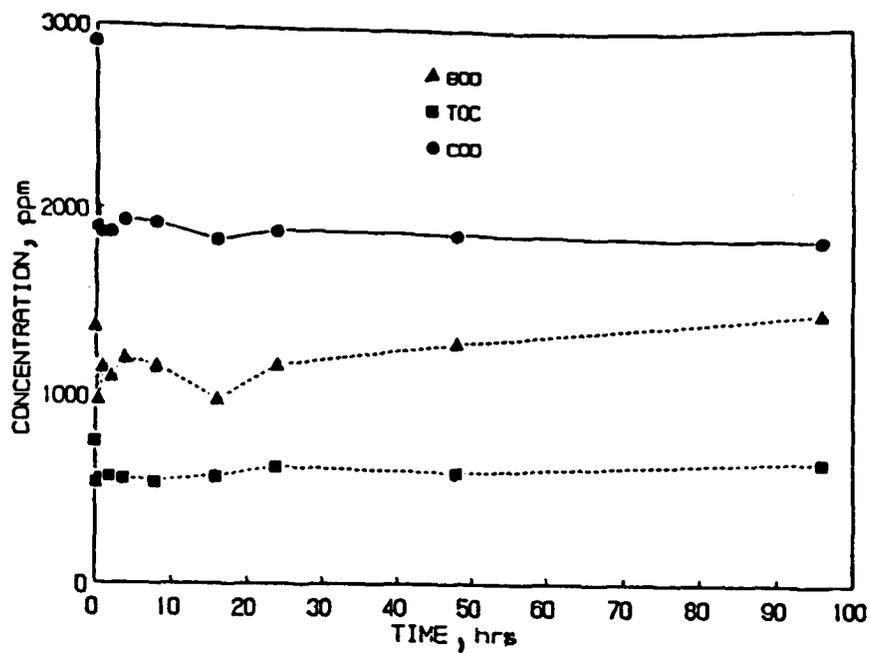
Figure 36. Cross pollutant AC adsorption equilibrium data
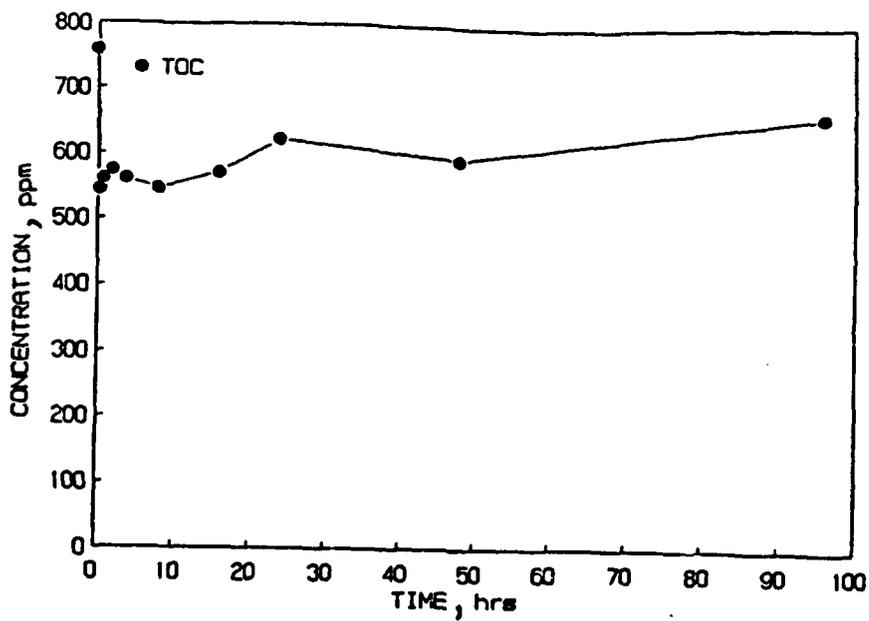
Figure 37. TOC AC adsorption equilibrium data using
a 30-g AC dose
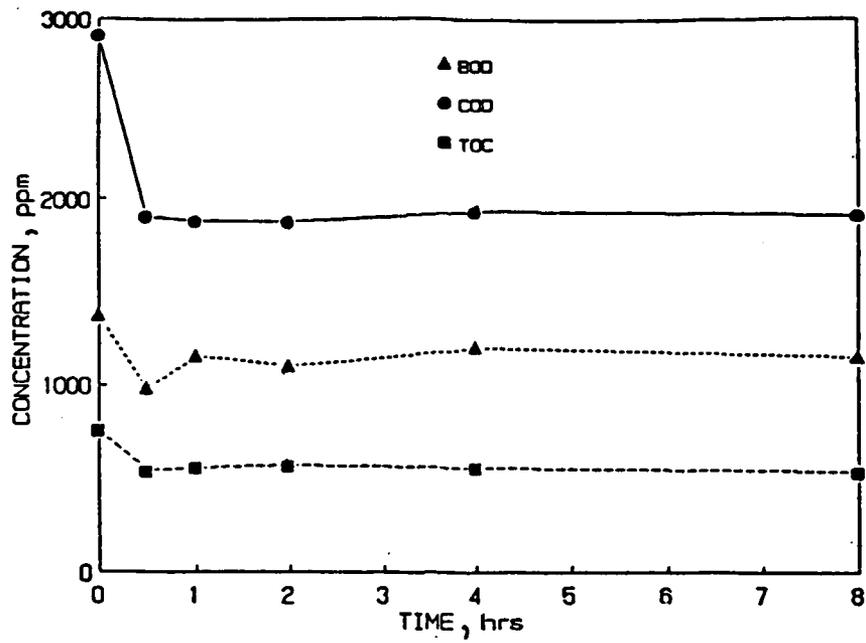
Figure 38. BOD, COD, and TOC AC equilibrium
data (concentrated plot)
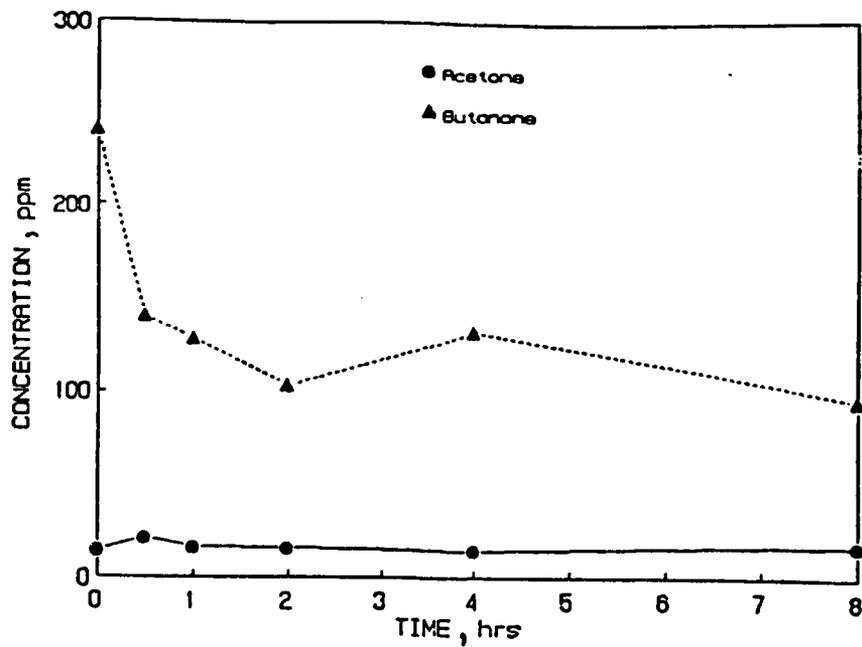
Figure 39. Acetone and butanone AC equilibrium
data (concentrated plot)
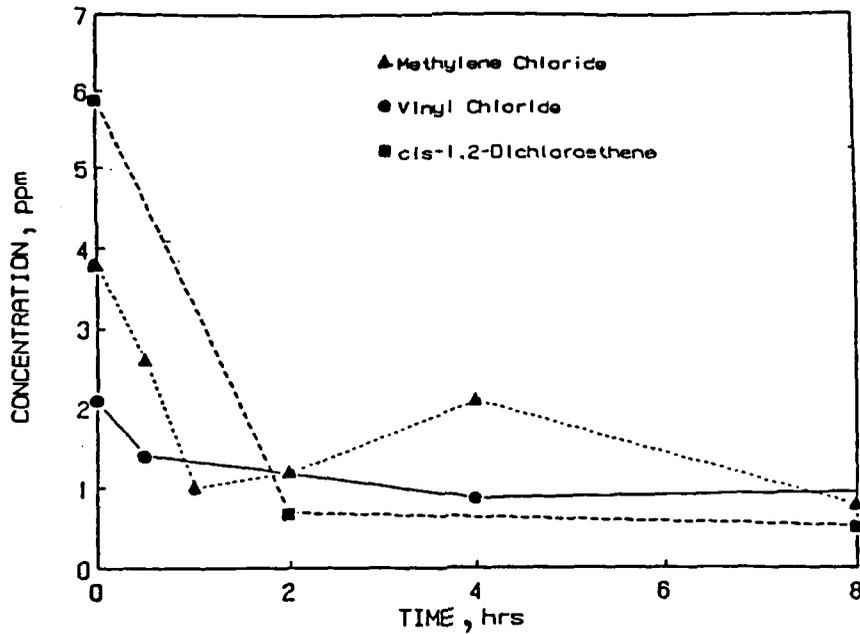
Figure 40. Methylene chloride, vinyl chloride, and
cis-1,2-dichloroethane AC data (concentrated plot)
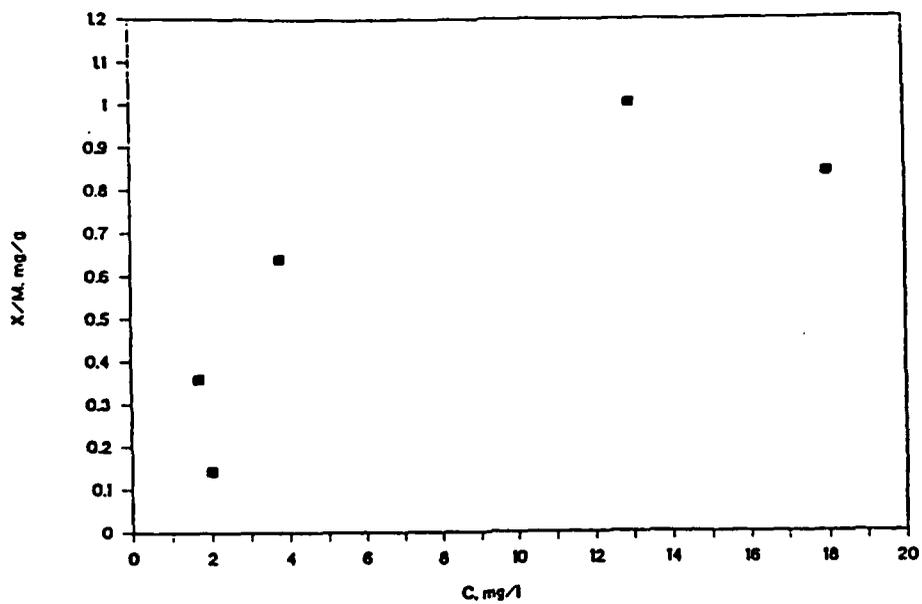
Figure 41. AC acetone equilibrium data
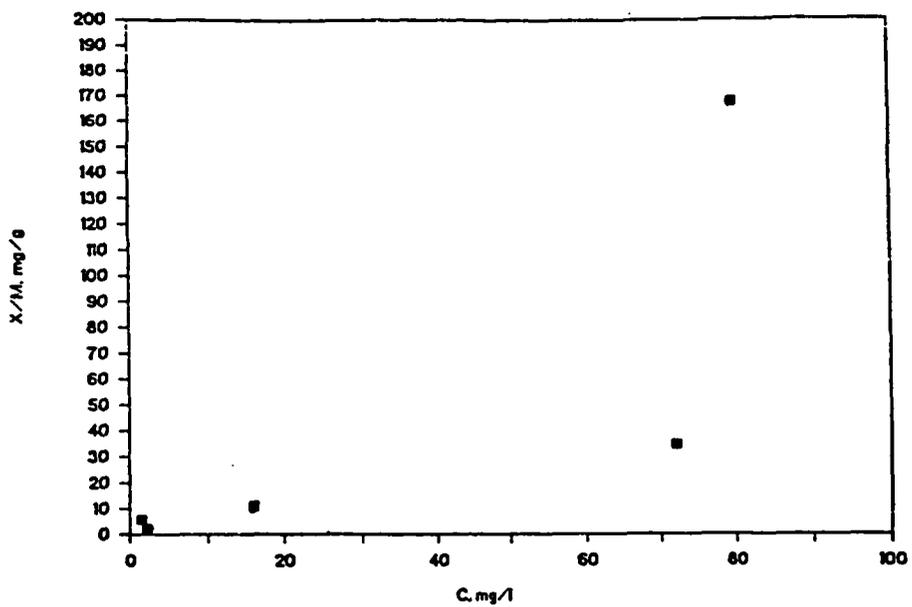
Figure 42.   AC 2-butanone equilibrium data
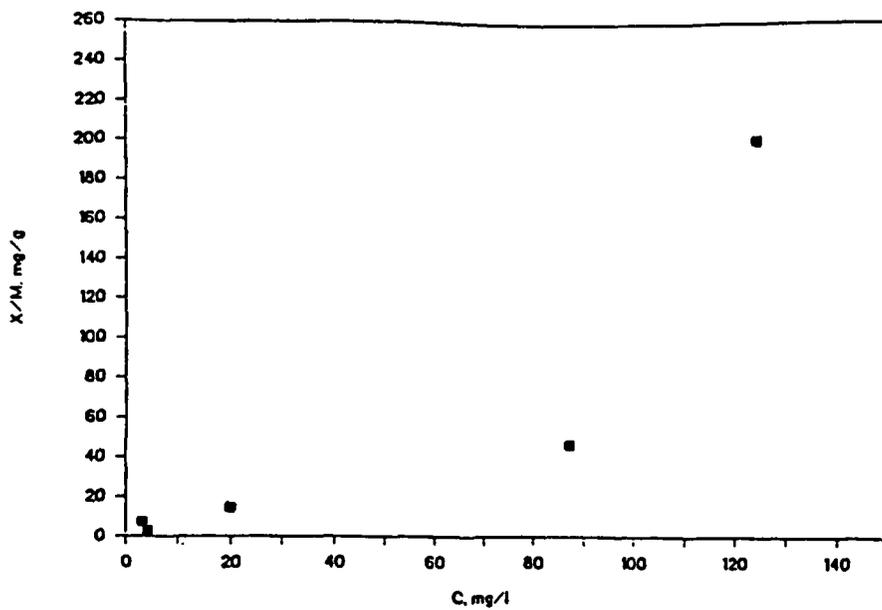
Figure 43.   AC TVOC equilibrium data
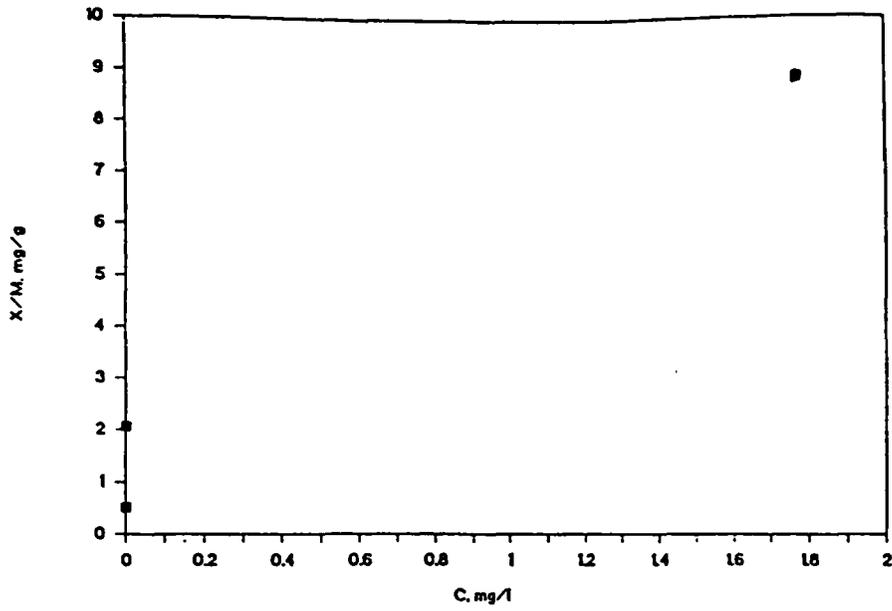
Figure 44. AC TBNA equilibrium data
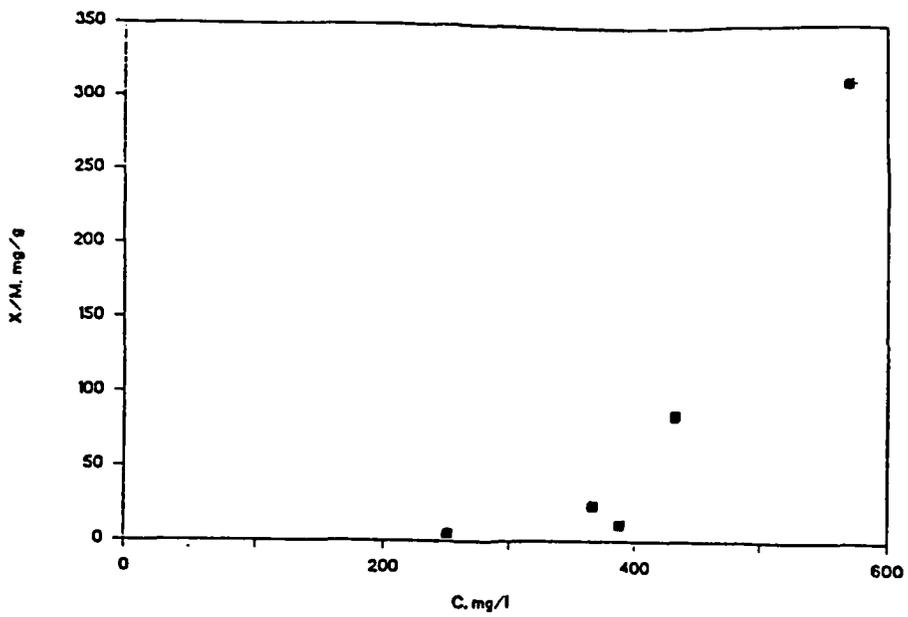
Figure 45. AC TOC equilibrium data
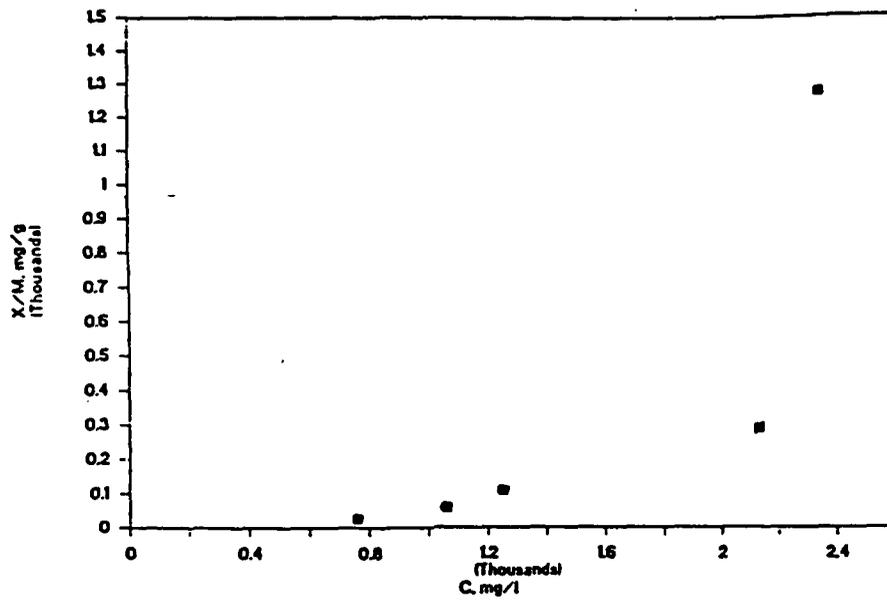
Figure 46.   AC COD equilibrium data
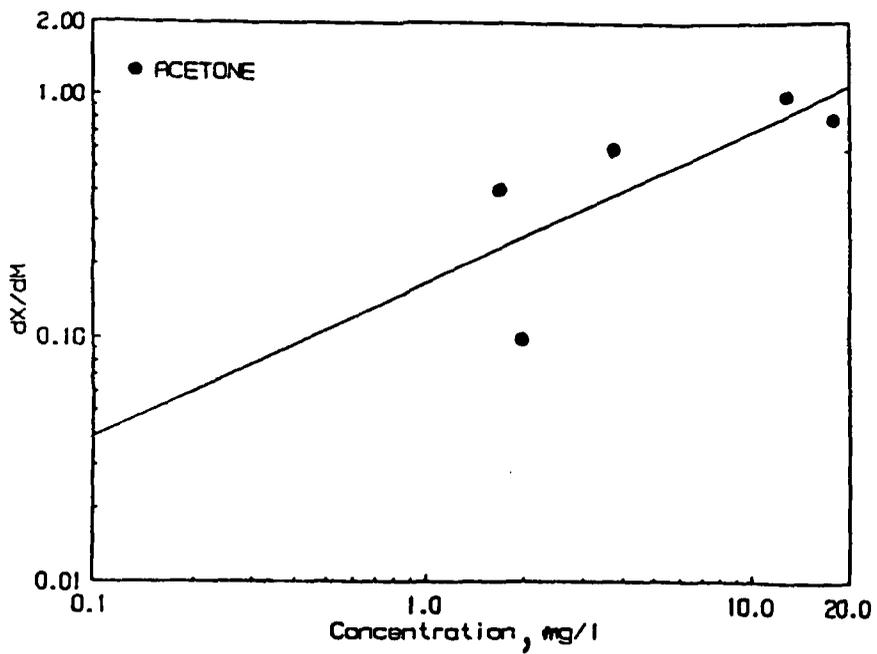
Figure 47.   Acetone adsorption isotherm
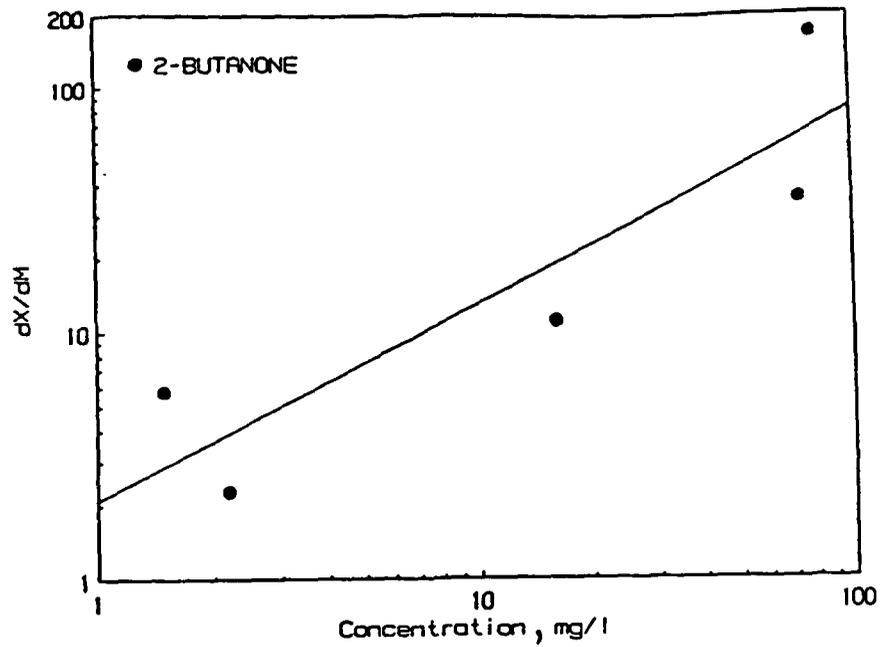
Figure 48. 2-butanone adsorption isotherm
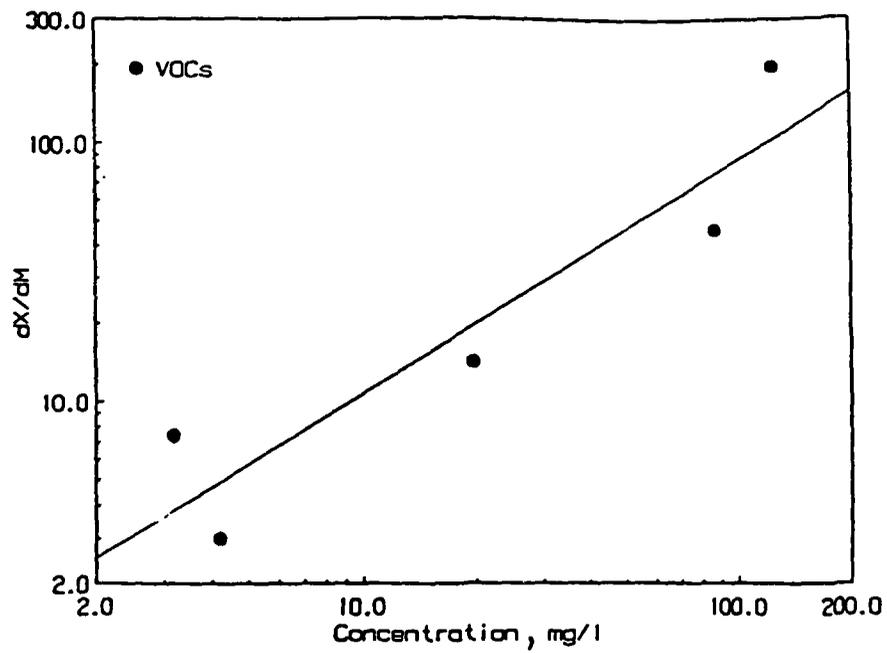
Figure 49. TVOC adsorption isotherm
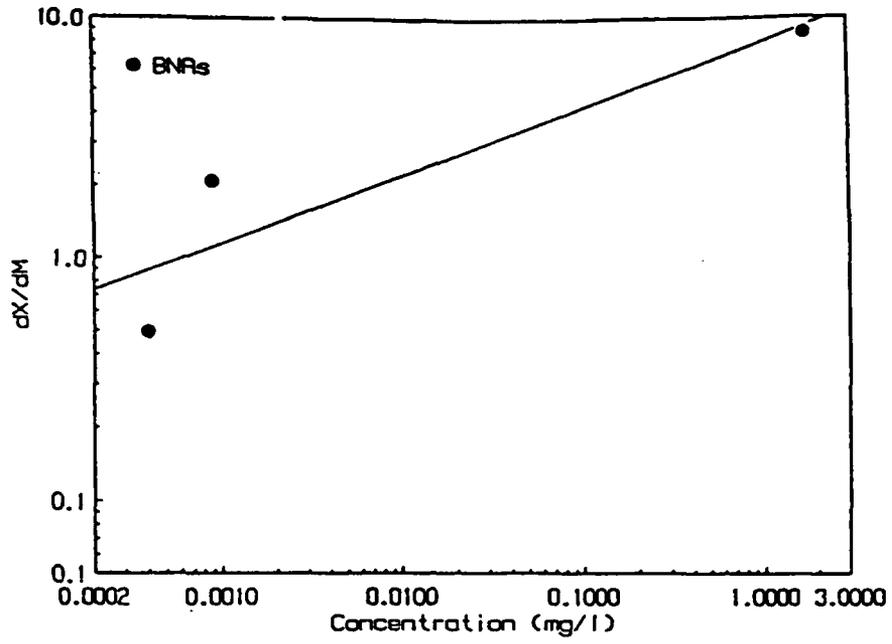
Figure 50. TBNA adsorption isotherm
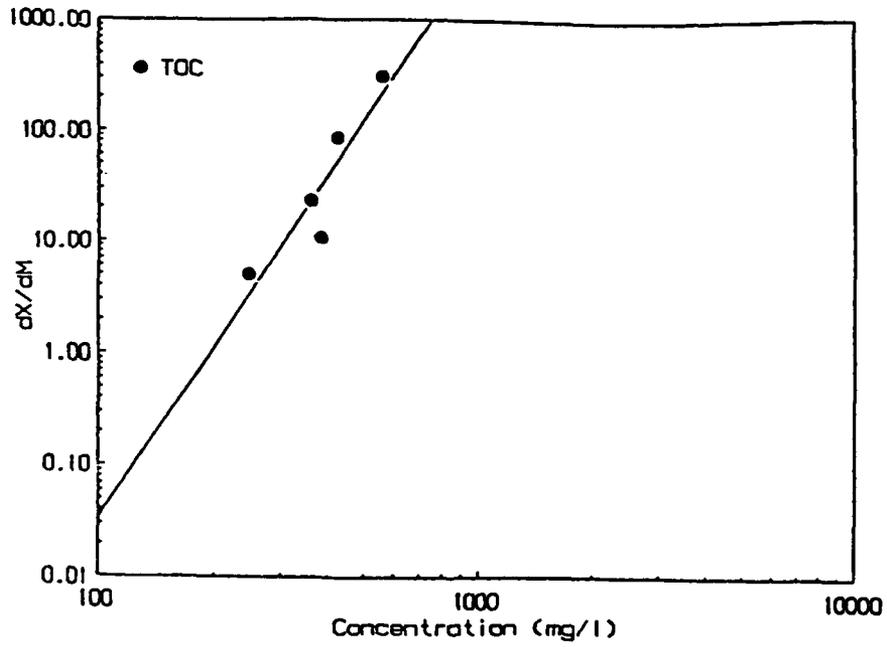
Figure 51. TOC adsorption isotherm
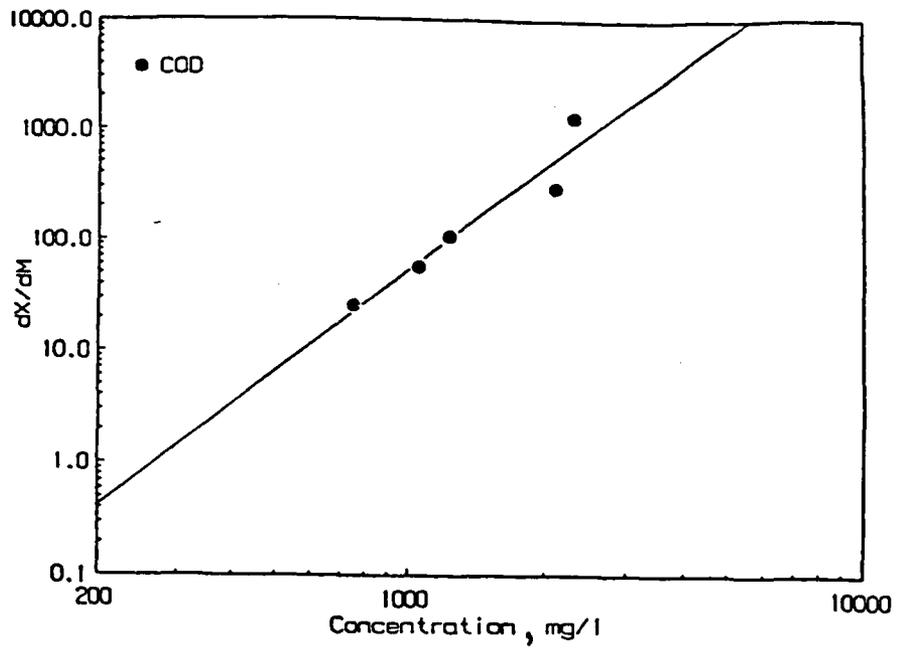
Figure 52. COD adsorption isotherm
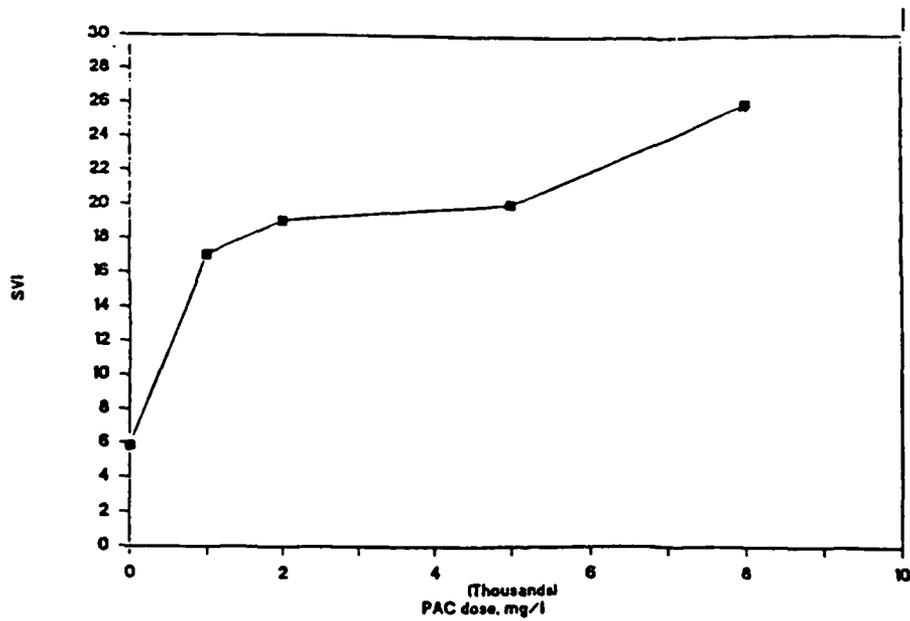
Figure 53. Effect of increased PAC dose on SVI
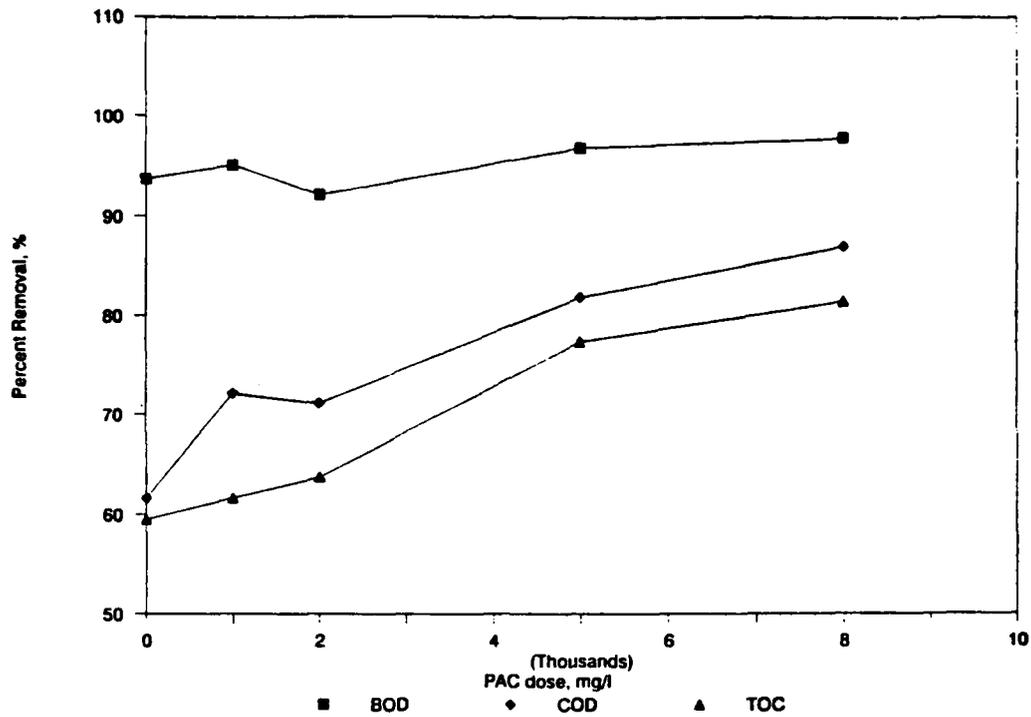
Figure 54. Effect of PAC dose on gross pollutant removals
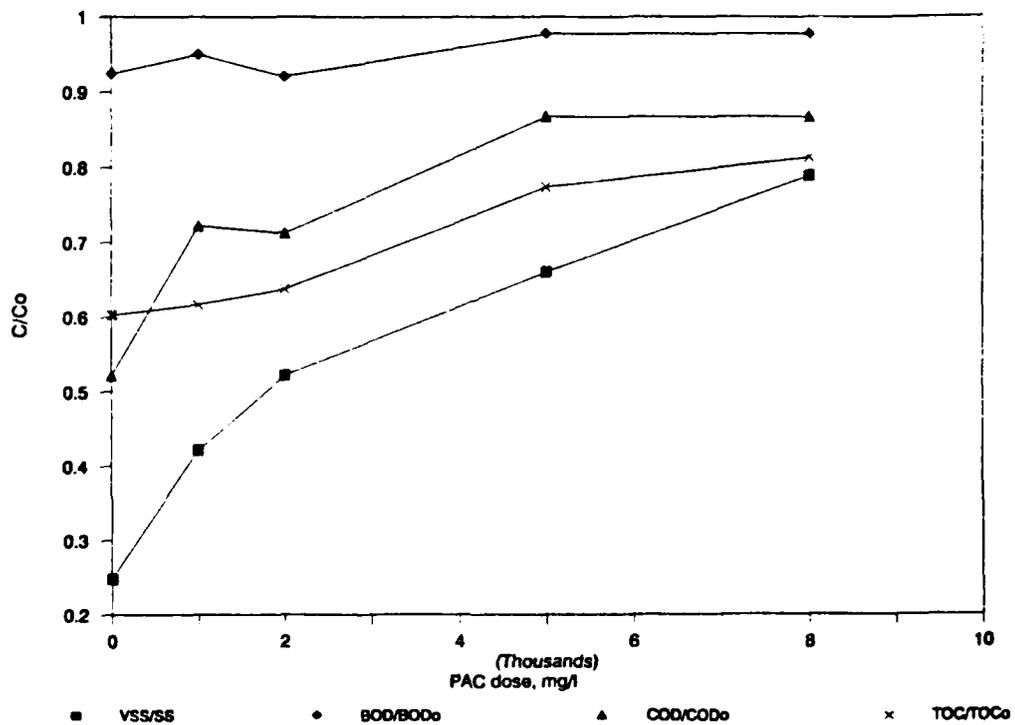
Figure 55. Effect of VSS/SS ratio increase on gross
pollutant removals
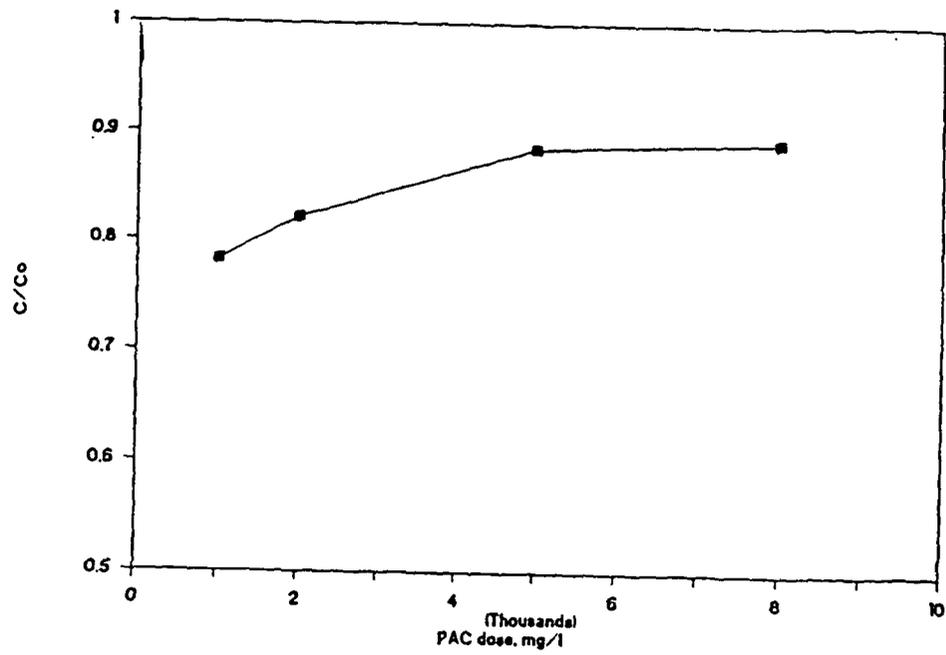
Figure 56.   Effect of increasing PAC dose on oil
             and grease removals

APPENDIX A: MICROBE MASTERS SUPER CEE ADDITION INSTRUCTIONS
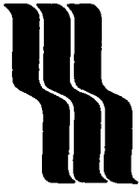
MICROBE MASTERS, INC.

"Biotechnology in Action"

PRODUCT DATA: MICRO PRO® CULTURES

Micro Pro® Mutant Bacterial Cultures
for Hazardous Waste Biodegradation

MICRO PRO® SUPER CEE

Micro Pro® Super Cee is a special blend of bacterial cultures
which were selected and mutated for use in creosote waste
cleanup. These cultures will effectively biodegrade
pentachlorophenol, poly nuclear aromatics, and other cresote
constituents. It has also proven effective with wastewaters
containing large amounts of aromatics, or extremely high BOD.

APPLICATION: Creosote waste sites.

FORM: Dry or liquid bacterial cultures. Liquid cultures:
55 gal. lined steel drums. Dry cultures: 25 or 50 lb.
fiber drums. Dry product is also available in water
soluble BAC-PAKS®(1/2#).

	Dry Cultures	Liquid Cultures
Appearance	Tan, free flowing powder	slightly turbid liquid
Odor	yeast-like	Faint grape-like odor
Bacteria Count	6.5 billion/gram	100 billion/gal minimum
Specific Gravity	0.6	1.0
pH	6.0 - 8.5	Neutral
Effective Temperature	50-110°F	50-110°F
Shelf Life	1 year	6 months
Moisture	15%	N/A

Baton Rouge • Houston • Atlanta • Baltimore • Tokyo • London • Vancouver

A3

DOSAGES:

Dosages for the products will vary with the specific situation and the particular goals of the waste site. For LSC reactor applicants, add enough bacteria to keep activity at a D.O.U.R. of 15-20 mg/l/hr. For land applications, use between 1-3 lbs. per 100 square feet depending on the concentration of contaminants to be biodegraded. For dosages in waste treatment systems consult our technical services department for recommended dosage.

HANDLING AND STORAGE:

Liquids and dry cultures must be stored in a cool dry place. Avoid temperatures above 110°F or below 40°F. After handling, wash hands with warm soapy water. Avoid excessive inhalation of the dry powder.

OPTIMUM CONDITIONS FOR APPLICATION:

Bacteria and enzymes in Micro Pro* products perform within a pH range or 6.0 - 8.5 with the optimum near pH 7.5. The temperature of the working solution or waste stream affects biological activity. Activity below 40°F and above 100°F can be significantly covered.

APPLICATION PROCEDURE:

Liquid product can be fed directly by pump or hand to the system. Dry product should be dispensed in water (one pound/two gallons water). Stir and allow to sit for two to three hours, after which the suspension should be stirred again and added to the system.

BAC-PAK* products can contain special wetting and emulsion agents and can be dispersed directly to the system.

For additional information or technical assistance, please contact:

Technical Service Department
MICROBE MASTERS, INC.
11814 Coursey Blvd.
suite 285
Baton Rouge, LA 70816
(504)665-1903
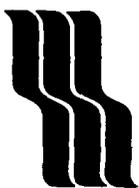
MICROBE MASTERS, INC.

504/665-1903

11814 COURSEY BOULEVARD • SUITE 285 • BATON ROUGE, LOUISIANA 70816 • FAX 504/664-8000

"Biotechnology-in-Action" ®

December 1. 1988

Mr. Mark Zappi
US ENGINEER WATERWAYS EXPERIMENT STATION
P.O. Box 631
Vicksburg, MS 39181-0631

Attention: CEWES-EE-S/Mr. Mark Zappi

Dear Mark:

Enclosed is general information on Microbe Masters bacterial products, including specific information on Micro Pro "Super Cee".

Our recommendations for maintaining physical parameters in association with the use of Micro Pro products are as follows;

1.   You should "slurry" the dry bacterial product before adding it to your pilot study. To do this, introduce the product into a flask of water, and allow the contents to stir for approximately 20 minutes. Allow the bran carrier to settle, and add supernatant to your lab reactor as the inoculum. This procedure allows the biomass to become active prior to contact with the waste.

2.   PH should be maintained between 6-8. The optimum pH level for biological treatment is approximately 7.2.

3.   Ammonia nitrogen (NH_3) should be kept at a minimum of 3 ppm. Sources for this nutrient are ammonium sulfate, ammonium phosphate, ammonium nitrate or technical grade diammonium phosphate.

4.   Orthophosphate (OPO_4) should be kept at a minimum of 3 ppm. Sources for OPO_4 are phosphoric acid, disodium phosphate, monosodium phosphate or technical grade diammonium phosphate.

5.   Temperature range for bacterial activity is between 55° and 110° F. Optimum temperature is 90° - 100° F.

6.   You should maintain a (minimum) dissolved oxygen residual of 1-2 ppm at all times.

Mark, I hope this information is helpful. Please do not hesitate to call me at (504) 665-1903 if I can answer any questions for you. Thank you for your interest in Microbe Master's products and services.

Sincerely,
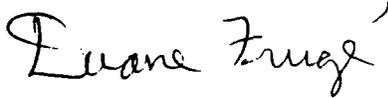
Duane Fruge'
Technical Engineer

DF/bs

enclosure: Microbe Master's Company Background
               Industrial and Municipal product list
               Micro Pro "Super Cee" data sheet
               MSDS
               Nutrient sheet
               Introduction sheet to ERI

APPENDIX B: PRIORITY POLLUTANT ANALYTICAL DETECTION LIMITS

Table B1

Organic Analytes and Detection Limits

Analyte	Detection Limit mg/ℓ
Chloromethane	0.010
Bromomethane	0.010
Vinyl chloride	0.010
Chloroethane	0.010
Methylene chloride	0.005
1,1-dichloroethene	0.005
1,1-dichloroethane	0.005
Trans-1,2-dichloroethene	0.005
Cis-1,2-dichloroethene	0.005
Chloroform	0.005
1,2-dichloroethane	0.005
1,1,1-trichloroethane	0.005
Carbon tetrachloride	0.005
Bromodichloromethane	0.005
1,2-dichloropropane	0.005
Trans-1,3-dichloropropene	0.005
Trichloroethene	0.005
Dibromochloromethane	0.005
Cis-1,3-dichloropropene	0.005
1,1,2-trichloroethane	0.005
Benzene	0.005
2-chloroethylvinylether	0.005
Bromoform	0.005
1,1,2,2-tetrachloroethane	0.005
Tetrachloroethene	0.005
Toluene	0.005
Chlorobenzene	0.005
Ethylbenzene	0.005
Acrolein	0.100
Acrylonitrile	0.100
Acetone	0.100

(Continued)

Analyte	Detection Limit mg/ℓ
2-butanone	0.100
Carbon disulfide	0.005
2-hexanone	0.050
4-methyl-2-pentanone	0.050
Styrene	0.005
Vinyl acetate	0.050
Total xylenes	0.005
Phenol	0.010
2-chlorophenol	0.010
2-nitrophenol	0.010
2,4-dimethylphenol	0.010
2,4-dichlorophenol	0.010
4-chloro-3-methylphenol	0.020
2,4,6-trichlorophenol	0.010
2,4-dinitrophenol	0.050
4-nitrophenol	0.050
2-methyl-4,6-dinitrophenol	0.050
Pentachlorophenol	0.050
Benzoic acid	0.050
2-methylphenol	0.010
4-methylphenol	0.010
2,4,5-trichlorophenol	0.010
Benzyl alcohol	0.020
N-nitrosodimethylamine	0.010
Bis(2-chloroisopropyl)ether	0.010
N-nitroso-di-n-propylamine	0.010
Nitrobenzene	0.010
Isophorone	0.010
Bis(2-chloroethoxy)methane	0.010
2,6-dinitrotoluene	0.010
2,4-dinitrotoluene	0.010
1,2-diphenylhydrazine	0.010

(Continued)

Analyte	Detection Limit mg/ℓ
Benzidine	0.050
3,3-dichlorobenzidine	0.020
Bis(2-chloroethyl)ether	0.010
1,3-dichlorobenzene	0.010
1,4-dichlorobenzene	0.010
1,2-dichlorobenzene	0.010
Hexachloroethane	0.010
1,2,4-trichlorobenzene	0.010
Naphthalene	0.010
Hexachlorobutadiene	0.010
Hexachlorocyclopentadiene	0.010
2-chloronaphthalene	0.010
Acenaphthylene	0.010
Dimethyl phthalate	0.010
Acenaphthene	0.010
Fluorene	0.010
Diethyl phthalate	0.010
4-chlorophenyl phenyl ether	0.010
N-nitrosodiphenyl amine	0.010
4-bromophenyl ether	0.010
Hexachlorobenzene	0.010
Phenanthrene	0.010
Anthracene	0.010
Dibutylphthalate	0.010
Fluoranthene	0.010
Pyrene	0.010
Butylbenzylphthalate	0.010
Chrysene	0.010
Benzo(a)anthracene	0.010
Bis(2-ethylhexyl)phthalate	0.010
Di-n-octylphthalate	0.010
Benzo(b)fluoranthene	0.010

(Continued)

Table B1 (Concluded)

Analyte	Detection Limit mg/ℓ
Benzo(k)fluoranthene	0.010
Benzo(a)pyrene	0.010
Indeno(1,2,3-c,d)pyrene	0.010
Dibenzo(A,H)anthracene	0.010
Benzo(G,H,I)perylene	0.010
Aniline	0.010
4-chloroaniline	0.020
Dibenzofuran	0.010
2-methylnaphthalene	0.010
2-nitroaniline	0.050
3-nitroaniline	0.050
4-nitroaniline	0.050
Total organic carbon	1.000

Table B2

Organic Analytes and Detection Limits

Analyte	Detection Limit mg/ℓ
Chloromethane	<0.001
Bromomethane	<0.001
Vinyl chloride	<0.001
Chloroethane	<0.001
Methylene chloride	<0.001
1,1-dichloroethene	<0.001
1,1-dichloroethane	<0.001
Trans-1,2-dichloroethene	<0.001
Cis-1,2-dichloroethene	<0.001
Chloroform	<0.001
1,2-dichloroethane	<0.001
1,1,1-trichloroethane	<0.001
Carbon tetrachloride	<0.001
Bromodichloromethane	<0.001
1,2-dichloropropane	<0.001
Trans-1,3-dichloropropene	<0.001
Trichloroethene	<0.001
Dibromochloromethane	<0.001
Cis-1,3-dichloropropene	<0.001
1,1,2-trichloroethane	<0.001
Benzene	<0.001
2-chloroethylvinylether	<0.001
Bromoform	<0.001
1,1,2,2-tetrachloroethane	<0.001
Tetrachloroethene	<0.001
Toluene	<0.001
Chlorobenzene	<0.001
Ethylbenzene	<0.001
Acrolein	<0.020
Acrylonitrile	<0.020
Acetone	<0.020

(Continued)

Analyte	Detection Limit mg/ℓ
2-butanone	<0.020
Carbon disulfide	<0.001
2-hexanone	<0.010
4-methyl-2-pentanone	<0.010
Styrene	<0.001
Vinyl acetate	<0.010
Total xylenes	<0.001
Phenol	<0.002
2-chlorophenol	<0.002
2-nitrophenol	<0.002
2,4-dimethylphenol	<0.002
2,4-dichlorophenol	<0.002
4-chloro-3-methylphenol	<0.0015
2,4,6-trichlorophenol	<0.0015
2,4-dinitrophenol	<0.0015
4-nitrophenol	<0.0015
2-methyl-4,6-dinitrophenol	<0.0015
Pentachlorophenol	<0.002
Benzoic acid	<0.030
2-methylphenol	<0.001
4-methylphenol	<0.001
2,4,5-trichlorophenol	<0.0015
Benzyl alcohol	<0.002
N-nitrosodimethylamine	<0.002
Bis(2-chloroisopropyl)ether	<0.0025
N-nitroso-di-n-propylamine	<0.0015
Nitrobenzene	<0.0025
Isophorone	<0.0025
Bis(2-chloroethoxy)methane	<0.0025
2,6-dinitrotoluene	<0.001
2,4-dinitrotoluene	<0.001
1,2-diphenylhydrazine	<0.001

(Continued)

Table B2 (Continued)

Analyte	Detection Limit mg/ℓ
Benzidine	<0.030
3,3-dichlorobenzidine	<0.015
Bis(2-chloroethyl)ether	<0.0015
1,3-dichlorobenzene	<0.002
1,4-dichlorobenzene	<0.002
1,2-dichlorobenzene	<0.0025
Hexachloroethane	<0.002
1,2,4-trichlorobenzene	<0.002
Naphthalene	<0.002
Hexachlorobutadiene	<0.0025
Hexachlorocyclopentadiene	<0.002
2-chloronaphthalene	<0.0015
Acenaphthylene	<0.0015
Dimethyl phthalate	<0.0015
Acenaphthene	<0.0015
Fluorene	<0.001
Diethyl phthalate	<0.0027
4-chlorophenyl phenyl ether	<0.001
N-nitrosodiphenyl amine	<0.0015
4-bromophenyl ether	<0.0015
Hexachlorobenzene	<0.0015
Phenanthrene	<0.001
Anthracene	<0.0025
Dibutylphthalate	<0.005
Fluoranthene	<0.0015
Pyrene	<0.0015
Butylbenzylphthalate	<0.0015
Chrysene	<0.0015
Benzo(a)anthracene	<0.0015
Bis(2-ethylhexyl)phthalate	<0.001
Di-n-octylphthalate	<0.0025
Benzo(b)fluoranthene	<0.0015

(Continued)

Table B2 (Concluded)

Analyte	Detection Limit mg/ℓ
Benzo(k)fluoranthene	<0.0015
Benzo(a)pyrene	<0.002
Indeno(1,2,3-c,d)pyrene	<0.0035
Dibenzo(A,H)anthracene	<0.0025
Benzo(G,H,I)perylene	<0.004
Aniline	<0.0015
4-chloroaniline	<0.002
Dibenzofuran	<0.001
2-methylnaphthalene	<0.002
2-nitroaniline	<0.010
3-nitroaniline	<0.010
4-nitroaniline	<0.010
Total organic carbon	1.000

APPENDIX C: UNREDUCED BIOLOGICAL TREATMENT DATA
              FOR ACCLIMATION STUDY

Table C1

Acclimation Phase

Temperature, Dissolved Oxygen, and pH Data

DATE	DAY	TEMPERATURE Celsius	DISSOLVED OXYGEN mg/l	pH INFLUENT
17 Jan 89	0	16	7.4	6.90
18 Jan 89	1	19	6.8	7.70
19 Jan 89	2A	17	7.1	7.30
20 Jan 89	2B	18	6.6	7.50
21 Jan 89	3	16	6.7	7.11
22 Jan 89	4	17	6.4	6.40
23 Jan 89	5	17	6.2	7.15
24 Jan 89	6	18	5.5	7.10
25 Jan 89	7	18	5.0	7.10
26 Jan 89	8	19	4.9	7.17
27 Jan 89	9	18	5.0	6.77
28 Jan 89	10	17	4.8	6.85
29 Jan 89	11	17	4.3	6.80
30 Jan 89	12	19	4.5	6.83
31 Jan 89	13	16	4.8	6 78
1 Feb 89	14	20	4.5	6.80
2 Feb 89	15	21	3.3	6.78
3 Feb 89	16	20	5.0	6.77
4 Feb 89	17	17	5.3	6.71
5 Feb 89	18	17	5.3	6.68
6 Feb 89*	19			
7 Feb 89	20	16	4.0	6.17
8 Feb 89	21	17	4.1	6.80
9 Feb 89	22	15	3.4	6.77
10 Feb 89	23	17	4.7	6.85
11 Feb 89	24	19	4.9	6.83
12 Feb 89	25	19	3.1	6.80
13 Feb 89	26	19	3.5	6.85
14 Feb 89	27	19	3.7	6.82
15 Feb 89	28	19	3.9	6.79
16 Feb 89	29	19	3.5	6.83
17 Feb 89	30	17	4.5	6.80
18 Feb 89	31	15	3.8	6.60
19 Feb 89	32	19	3.5	6.80
20 Feb 89	33	19	3.8	6.64
21 Feb 89	34	19	2.6	6.58
22 Feb 89	35	19	3.5	6.67
23 Feb 89	36	18	3.7	6.74
24 Feb 89	37	18	3.8	6.83
25 Feb 89	38	17	5.3	6.80

(Continued)

* Electricity off.

C3

DATE	DAY	TEMPERATURE Celsius	DISSOLVED OXYGEN mg/1	pH INFLUENT
26 Feb 89	39	18	4.2	6.75
27 Feb 89	40	19	2.8	6.80
28 Feb 89	41	18	3.8	6.83
1 Mar 89	42	16	2.8	6.85
2 Mar 89	43	21	2.8	6.84
3 Mar 89	44	18	3.9	6.92
4 Mar 89	45	17	3.6	6.95
5 Mar 89	46	18	2.1	6.94
6 Mar 89	47	19	5.5	6.89
7 Mar 89	48	18	3.1	6.58
8 Mar 89*	49 10g	18	3.9	6.73
9 Mar 89	50 10g	18	3.2	6.78
10 Mar 89	51 10g	18	1.5	6.89
11 Mar 89	52 5g	17	4.2	6.80
12 Mar 89	53 5g	19	3.5	7.10
13 Mar 89	54 5g	18	4.2	6.90
14 Mar 89	55 2g	20	3.6	6.90
15 Mar 89	56 2g	21	4.5	6.87
16 Mar 89	57 1g	18	2.8	6.90
17 Mar 89	58 1g	18	2.9	6.86
18 Mar 89	59 1g	21	3.0	6.80
19 Mar 89	60 1g	18	3.8	6.95
20 Mar 89	61 .5g	18	3.5	6.95
21 Mar 89	62 .5g	18	2.3	6.90
22 Mar 89	63 .5g	20	3.8	6.88
23 Mar 89	64 .5g	16	4.2	6.88
24 Mar 89	65 .5g	18	2.2	6.83
25 Mar 89	66 .5g	18	2.9	6.97
26 Mar 89	67 .5g	19	3.9	6.95
27 Mar 89	68	20	2.4	7.16
28 Mar 89	69	21	3.0	6.56
29 Mar 89	70	22	3.5	6.71
30 Mar 89	71	19	4.0	6.80
31 Mar 89	72	18	4.0	6.80
1 Apr 89	73	18	4.5	6.79
2 Apr 89	74	19	2.3	6.80
3 Apr 89	75	21	3.7	6.75
4 Apr 89	76	23	3.5	6.83
5 Apr 89	77	17	3.6	6.89
6 Apr 89	78	16	3.5	6.81
7 Apr 89	79	17	4.3	6.77
8 Apr 89	80	20	5.5	
9 Apr 89	81	17	3.5	6.77
10 Apr 89	82	15	4.4	6.81

(Continued)

* Super Cee added.

DATE	DAY	TEMPERATURE Celsius	DISSOLVED OXYGEN mg/l	pH INFLUENT
11 Apr 89	83	15	4.8	6.81
12 Apr 89	84	15	4.3	6.86
13 Apr 89	85	16	4.4	6.90
14 Apr 89	86	18	3.6	6.90
15 Apr 89	87	19	6.0	6.85
16 Apr 89	88	17	4.2	6.90
17 Apr 89	89	18	4.0	6.59
18 Apr 89	90	20	4.2	6.74
19 Apr 89	91	21	4.3	6.63
20 Apr 89	92	19	4.3	6.80
21 Apr 89	93	17	4.2	6.71
22 Apr 89	94	18	6.4	
23 Apr 89	95	22	2.8	
24 Apr 89	96	21	4.2	6.73
25 Apr 89	97	21	4.0	6.84
26 Apr 89	98	20	4.0	6.74
27 Apr 89	99	21	4.3	6.83
28 Apr 89	100	23	3.9	6.83
29 Apr 89	101	22	4.0	6.86
30 Apr 89	102	22	4.2	6.85
1 May 89	103	21	4.1	6.81
2 May 89	104	20	3.4	6.92
3 May 89	105	20	4.4	6.88
4 May 89	106	21	4.2	6.92
5 May 89	107	20	3.9	6.88
6 May 89	108	21	4.3	7.38
7 May 89	109	23	6.2	6.92
8 May 89	110	19	4.4	6.84
9 May 89	111	23	3.3	6.84
10 May 89	112	21	4.4	6.54
AVERAGE		18.6	4.1	6.84
STANDARD DEVIATION		1.9	1.1	0.2
PERCENT REDUCTION				

Table C2

Acclimation Phase

Salinity and Conductivity Data

DATE	DAY	SALINITY parts/thousand		CONDUCTIVITY micromhos/cm	
		AERATION TANK	INFLUENT	AERATION TANK	INFLUENT
17 Jan 89	0	0.01	0.02	550	402
18 Jan 89	1	0.01	0.05	600	380
19 Jan 89	2A	0.03	0.05	650	830
20 Jan 89	2B	0.05	0.05	750	850
21 Jan 89	3	0.05	0.05	750	750
22 Jan 89	4	0.05	0.06	820	1000
23 Jan 89	5	0.05	0.05	875	850
24 Jan 89	6				
25 Jan 89	7	0.05	0.05	950	1100
26 Jan 89	8	0.05	0.05	1000	1120
27 Jan 89	9	0.05	0.07	1000	1200
28 Jan 89	10	0.05	1.00	1100	1500
29 Jan 89	11	0.05	0.05	1200	1750
30 Jan 89	12	0.08	0.05	1300	1800
31 Jan 89	13	0.75	1.25	1030	2000
1 Feb 89	14	0.75	1.20	1100	2120
2 Feb 89	15	1.0	1.5	1500	2250
3 Feb 89	16	1.0	1.5	1650	2500
4 Feb 89	17	1.0	1.5	1550	2500
5 Feb 89	18	1.0	2.0	1700	2550
6 Feb 89*	19				
7 Feb 89	20				
8 Feb 89	21	1.3	2.0	2000	3300
9 Feb 89	22	1.2	2.0	2100	3200
10 Feb 89	23	1.3	2.0	2150	3250
11 Feb 89	24	1.3	2.0	2200	3100
12 Feb 89	25	1.5	2.5	2250	3050
13 Feb 89	26	1.3	2.0	2400	3500
14 Feb 89	27	1.3	2.5	2400	3200
15 Feb 89	28	1.3	2.3	2350	3250
16 Feb 89	29	1.5	2.5	2480	3500
17 Feb 89	30	1.5	2.5	2350	3220
18 Feb 89	31				
19 Feb 89	32	1.5	2.5	2500	3050
20 Feb 89	33	1.5	2.5	2450	3000
21 Feb 89	34	1.5	2.5	2550	3700
22 Feb 89	35	1.5	2.5	2450	2800
23 Feb 89	36	1.5	2.5	2500	3500
24 Feb 89	37	1.8	2.3	2650	3300
25 Feb 89	38	1.5	2.0	2450	3120

(Continued)

* Electricity off.

DATE	DAY	SALINITY parts/thousand		CONDUCTIVITY micromhos/cm	
		AERATION TANK	INFLUENT	AERATION TANK	INFLUENT
26 Feb 89	39				
27 Feb 89	40	1.5	2.0	2500	3250
28 Feb 89	41	1.5	2.0	2450	3150
1 Mar 89	42	1.5	2.0	2450	3500
2 Mar 89	43	1.5	2.0	2500	3200
3 Mar 89	44	1.5	2.0	2420	3350
4 Mar 89	45	1.5	2.5	2500	2900
5 Mar 89	46	1.5	2.5	2420	3000
6 Mar 89	47	1.5	2.0	2550	3450
7 Mar 89	48	1.5	2.0	2550	3100
8 Mar 89*	49, 10	1.5	2.0	2600	3350
9 Mar 89	50, 10	1.5	2.0	2650	3650
10 Mar 89	51, 10	1.8	2.5	2500	3180
11 Mar 89	52, 5g	1.5	1.5	2450	2850
12 Mar 89	53, 5g				
13 Mar 89	54, 5g	1.7	2.5	2700	3760
14 Mar 89	55, 2g	1.5	2.0	2800	3650
15 Mar 89	56, 2g	1.5	2.0	2150	3400
16 Mar 89	57, 1g	1.5	2.0	2550	3300
17 Mar 89	58, 1g	1.5	2.0	2600	3400
18 Mar 89	59, 1g				
19 Mar 89	60, 1g				
20 Mar 89	61, .5	1.5	1.8	2550	3050
21 Mar 89	62, .5g				
22 Mar 89	63, .5	1.5	1.8	2550	2950
23 Mar 89	64, .5	1.5	2.0	2600	3150
24 Mar 89	65, .5	1.5	2.0	2750	3550
25 Mar 89	66, .5g				
26 Mar 89	67, .5g				
27 Mar 89	68	1.5	2.0	2600	3250
28 Mar 89	69	1.5	2.0	2650	3400
29 Mar 89	70	1.5	2.0	2700	3350
30 Mar 89	71	1.5	1.8	2600	3050
31 Mar 89	72	1.5	2.1	2500	3100
1 Apr 89	73	1.5	2.5	2400	2730
2 Apr 89	74				
3 Apr 89	75	1.5	2.0	2700	3700
4 Apr 89	76	1.5	1.5	2650	2900
5 Apr 89	77	1.3	1.5	2500	3100
6 Apr 89	78	1.5	1.8	2400	2900
7 Apr 89	79	1.5	1.9	2400	2950
8 Apr 89	80				
9 Apr 89	81				

(Continued)

* Super Cee added.

Table C2 (Concluded)

DATE	DAY	SALINITY parts/thousand		CONDUCTIVITY micromhos/cm	
		AERATION TANK	INFLUENT	AERATION TANK	INFLUENT
10 Apr 89	82	1.5	2.5	2300	3100
11 Apr 89	83	1.3	1.8	2300	2800
12 Apr 89	84	1.5	2.0	2450	3600
13 Apr 89	85	1.5	2.0	2350	3000
14 Apr 89	86	1.5	2.0	2400	3100
15 Apr 89	87				
16 Apr 89	88				
17 Apr 89	89	1.3	2.3	2150	3200
18 Apr 89	90	1.5	1.9	2500	3050
19 Apr 89	91	1.5	2.0	2500	3150
20 Apr 89	92	1.5	2.5	2500	2750
21 Apr 89	93	1.5	2.3	2600	3850
22 Apr 89	94				
23 Apr 89	95				
24 Apr 89	96	1.5	2.0	2600	2900
25 Apr 89	97	1.5	1.8	2550	2900
26 Apr 89	98	1.5	2.0	2600	3650
27 Apr 89	99	1.5	2.5	2600	3730
28 Apr 89	100	1.5	2.0	2650	3400
29 Apr 89	101				
30 Apr 89	102				
1 May 89	103	1.3	1.5	2500	2700
2 May 89	104	1.3	1.5	2450	2800
3 May 89	105	1.5	2.0	2500	2900
4 May 89	106	1.5	2.4	2500	3050
5 May 89	107	1.5	2.0	2500	3250
6 May 89	108				
7 May 89	109				
8 May 89	110	1.5	2.0	2400	2900
9 May 89	111	1.3	1.3	2550	2450
10 May 89	112	1.5	2.0	2700	3050
AVERAGE		1.2	1.8	2189	2830
STANDARD DEVIATION		0.5	0.7	613.2	816.4

Table C3

Acclimation Phase

Sludge Studies Volume Index, Suspended Solids,

Volatile Suspended Solids Data

DATE	DAY	SLUDGE VOLUME INDEX mg/l	SUSPENDED SOLIDS mg/l	VOLATILE SUSPENDED SOLIDS mg/l
17 Jan 89	0	69.64	933.33	723.33
18 Jan 89	1	96.36	778.33	633.33
19 Jan 89	2A	98.36	711.66	591.66
20 Jan 89	2B	69.63	861.66	688.33
21 Jan 89	3			
22 Jan 89	4			
23 Jan 89	5	177.66	985.33	815.66
24 Jan 89	6	466.76	1178.33	1003.33
25 Jan 89	7	626.75	1308.33	1013.10
26 Jan 89	8	530.39	1508.33	1136.67
27 Jan 89	9	473.53	1668.33	1195.00
28 Jan 89	10	389.68		
29 Jan 89	11	269.78		
30 Jan 89	12	171.75	1805.00	880.00
31 Jan 89	13	194.63	1926.67	1198.33
1 Feb 89	14	112.73	2173.33	1306.66
2 Feb 89	15	113.02	2035.00	1158.33
3 Feb 89	16	67.94	2870.00	1488.33
4 Feb 89	17			
5 Feb 89	18			
6 Feb 89*	19			
7 Feb 89	20			
8 Feb 89	21	44.56	3478.33	1681.66
9 Feb 89	22	80.80	1918.33	948.33
10 Feb 89	23	41.00	3535.00	1283.00
11 Feb 89	24			
12 Feb 89	25			
13 Feb 89	26	79.66	2385.00	1116.66
14 Feb 89	27	42.91	5126.67	2136.00
15 Feb 89	28	43.94	5233.33	2175.00
16 Feb 89	29	35.00	5848.00	2226.00
17 Feb 89	30	32.50		
18 Feb 89	31			
19 Feb 89	32	39.33		
20 Feb 89	33	39.33		
21 Feb 89	34	31.29	7031.60	2438.00
22 Feb 89	35	29.00	7121.00	2510.00
23 Feb 89	36	32.00	7016.00	2328.00
24 Feb 89	37	52.20		
25 Feb 89	38			

(Continued)

* Electricity off.

DATE	DAY	SLUDGE VOLUME INDEX mg/l	SUSPENDED SOLIDS mg/l	VOLATILE SUSPENDED SOLIDS mg/l
26 Feb 89	39			
27 Feb 89	40	52.84	7191.11	2473.33
28 Feb 89	41	51.63	8134.44	2676.66
1 Mar 89	42	57.41		
2 Mar 89	43	59.72	8036.00	2606.66
3 Mar 89	44	71.39	7003.33	2430.33
4 Mar 89	45			
5 Mar 89	46			
6 Mar 89	47	52.24	8996.66	2746.66
7 Mar 89	48	64.24	7326.66	1963.33
8 Mar 89*	49, 10g	55.96	8220.00	1963.33
9 Mar 89	50, 10g	69.58	6323.33	2183.33
10 Mar 89	51, 10g	67.50	6370.00	2323.00
11 Mar 89	52, 5g			
12 Mar 89	53, 5g			
13 Mar 89	54, 5g			
14 Mar 89	55, 2g	68.88	5806.66	2053.00
15 Mar 89	56, 2g	69.19	5926.70	2120.00
16 Mar 89	57, 1g	79.70	5263.33	1826.66
17 Mar 89	58, 1g	80.43	4973.33	2013.33
18 Mar 89	59, 1g			
19 Mar 89	60, 1g			
20 Mar 89	61, .5g	50.87	6683.33	2366.00
21 Mar 89	62, .5g	55.20	6250.00	2303.00
22 Mar 89	63, .5g	38.30	4830.00	1856.66
23 Mar 89	64, .5g	40.53	4436.66	1843.33
24 Mar 89	65, .5g	30.31	6103.33	2243.33
25 Mar 89	66, .5g			
26 Mar 89	67, .5g			
27 Mar 89	68	14.54	7220.00	2436.66
28 Mar 89	69	20.78		
29 Mar 89	70	20.00	6003.33	2183.33
30 Mar 89	71	20.17	7930.00	2873.00
31 Mar 89	72			
1 Apr 89	73			
2 Apr 89	74			
3 Apr 89	75	17.74	7326.66	2573.33
4 Apr 89	76	14.12	8143.33	2970.00
5 Apr 89	77	13.75	6321.00	2986.66
6 Apr 89	78	17.26	6083.33	2074.66
7 Apr 89	79	19.34	7237.33	2362.33
8 Apr 89	80			
9 Apr 89	81			

(Continued)

* Super Cee added.

Table C3 (Concluded)

DATE	DAY	SLUDGE VOLUME INDEX mg/l	SUSPENDED SOLIDS mg/l	VOLATILE SUSPENDED SOLIDS mg/l
10 Apr 89	82	17.05	7917.78	2617.78
11 Apr 89	83	18.97	6853.33	2277.66
12 Apr 89	84	16.50	9088.80	2826.66
13 Apr 89	85	17.60	8528.88	2819.99
14 Apr 89	86	18.00	8490.00	2726.66
15 Apr 89	87			
16 Apr 89	88			
17 Apr 89	89	14.50	8996.66	3030.00
18 Apr 89	90	13.70	8760.00	2696.66
19 Apr 89	91	11.90	9226.66	2746.66
20 Apr 89	92	15.76	7613.33	2420.00
21 Apr 89	93	24.50	7756.00	2410.00
22 Apr 89	94			
23 Apr 89	95			
24 Apr 89	96	25.64	7410.00	2346.66
25 Apr 89	97	23.32	7933.33	2333.33
26 Apr 89	9,	21.69	8760.00	2546.66
27 Apr 89	99	16.17	9890.00	2623.33
28 Apr 89	100	21.24	8760.00	2833.33
29 Apr 89	101			
30 Apr 89	102			
1 May 89	103	15.61	9290.00	2556.66
2 May 89	104	16.00	8753.33	2640.00
3 May 89	105	15.96	8146.66	2310.00
4 May 89	106	18.55	7546.66	2066.66
5 May 89	107	23.36	7171.46	2409.63
6 May 89	108			
7 May 89	109			
8 May 89	110	17.27	8396.66	2540.00
9 May 89	111	17.96	7796.66	2226.66
10 May 89	112	19.00	7893.33	2283.33
AVERAGE		77.1	5952.8	2074.2
STANDARD DEVIATION		118.0	2665.4	657.6
PERCENT REDUCTION				

Table C4

Acclimation Phase

Chemical Oxygen Demand and Total Organic Carbon Data

DATE	DAY	COD ppm		TOC ppm	
		INFLUENT	EFFLUENT	INFLUENT	EFFLUENT
17 Jan 89	0				
18 Jan 89	1				
19 Jan 89	2A	466	63	165.0	15.2
20 Jan 89	2B				
21 Jan 89	3				
22 Jan 89	4				
23 Jan 89	5				
24 Jan 89	6				
25 Jan 89	7	1060	112	286.2	29.6
26 Jan 89	8				
27 Jan 89	9	536	150	305.4	34.7
28 Jan 89	10				
29 Jan 89	11				
30 Jan 89	12				
31 Jan 89	13	811	220	443.0	54.8
1 Feb 89	14				
2 Feb 89	15				
3 Feb 89	16	2460	301	548.0	75.0
4 Feb 89	17				
5 Feb 89	18				
6 Feb 89*	19				
7 Feb 89	20				
8 Feb 89	21				
9 Feb 89	22				
10 Feb 89	23	3400	517	828.0	184.5
11 Feb 89	24				
12 Feb 89	25				
13 Feb 89	26				
14 Feb 89	27	3620	668	742.5	220.5
15 Feb 89	28				
16 Feb 89	29	3560	668	796.5	229.5
17 Feb 89	30				
18 Feb 89	31				
19 Feb 89	32				
20 Feb 89	33				
21 Feb 89	34	3670	687	825.0	235.5
22 Feb 89	35				
23 Feb 89	36	4070	662	780.0	213.0
24 Feb 89	37				
25 Feb 89	38				

(Continued)

* Electricity added.

C12

DATE	DAY	COD ppm		TOC ppm	
		INFLUENT	EFFLUENT	INFLUENT	EFFLUENT
26 Feb 89	39				
27 Feb 89	40				
28 Feb 89	41				
1 Mar 89	42	4450	683	885.0	234.0
2 Mar 89	43				
3 Mar 89	44				
4 Mar 89	45				
5 Mar 89	46				
6 Mar 89	47	4140	1364	858.0	234.0
7 Mar 89	48				
8 Mar 89*	49, 10g				
9 Mar 89	50, 10g				
10 Mar 89	51, 10g				
11 Mar 89	52, 5g				
12 Mar 89	53, 5g				
13 Mar 89	54, 5g				
14 Mar 89	55, 2g	4760	846	947.0	285.0
15 Mar 89	56, 2g				
16 Mar 89	57, 1g				
17 Mar 89	58, 1g				
18 Mar 89	59, 1g				
19 Mar 89	60, 1g				
20 Mar 89	61, .5g	4650	1760	918.0	257.0
21 Mar 89	62, .5g				
22 Mar 89	63, .5g				
23 Mar 89	64, .5g				
24 Mar 89	65, .5g	3870	1700	929.0	237.0
25 Mar 89	66, .5g				
26 Mar 89	67, .5g				
27 Mar 89	68				
28 Mar 89	69	3910	1700	825.0	244.0
29 Mar 89	70				
30 Mar 89	71				
31 Mar 89	72				
1 Apr 89	73				
2 Apr 89	74				
3 Apr 89	75				
4 Apr 89	76				
5 Apr 89	77				
6 Apr 89	78				
7 Apr 89	79	2310	820	843.0	246.0
8 Apr 89	80				
9 Apr 89	81				

(Continued)

* Super Cee added.

Table C4 (Concluded)

DATE	DAY	COD ppm		TOC ppm	
		INFLUENT	EFFLUENT	INFLUENT	EFFLUENT
10 Apr 89	82				
11 Apr 89	83				
12 Apr 89	84	2330	822	1129.5	255.0
13 Apr 89	85				
14 Apr 89	86				
15 Apr 89	87				
16 Apr 89	88				
17 Apr 89	89	1170	721		
18 Apr 89	90				
19 Apr 89	91				
20 Apr 89	92				
21 Apr 89	93				
22 Apr 89	94	1180	818		
23 Apr 89	95				
24 Apr 89	96				
25 Apr 89	97	1140	757		
26 Apr 89	98				
27 Apr 89	99	1200	750		
28 Apr 89	100				
29 Apr 89	101				
30 Apr 89	102				
1 May 89	103				
2 May 89	104				
3 May 89	105				
4 May 89	106				
5 May 89	107				
6 May 89	108				
7 May 89	109				
8 May 89	110				
9 May 89	111				
10 May 89	112				
AVERAGE		2671.0	763.1	725.2	182.5
STANDARD DEVIATION		1453.9	478.1	256.2	90.0
PERCENT REDUCTION			71.43		74.84

Table C5

Acclimation Phase

Biochemical Oxygen Demand Data

		BOD mg/l	
DATE	DAY	INFLUENT	EFFLUENT
17 Jan 89	0	202.0	15.7
18 Jan 89	1	211.0	33.1
19 Jan 89	2A		
20 Jan 89	2B	364.9	26.9
21 Jan 89	3		
22 Jan 89	4		
23 Jan 89	5		
24 Jan 89	6		
25 Jan 89	7	597.6	
26 Jan 89	8		
27 Jan 89	9	729.0	11.2
28 Jan 89	10		
29 Jan 89	11		
30 Jan 89	12		
31 Jan 89	13		
1 Feb 89	14		
2 Feb 89	15	1455.0	15.6
3 Feb 89	16	1455.0	14.7
4 Feb 89	17		
5 Feb 89	18		
6 Feb 89*	19		
7 Feb 89	20		
8 Feb 89	21		
9 Feb 89	22		
10 Feb 89	23	1715.5	16.0
11 Feb 89	24		
12 Feb 89	25		
13 Feb 89	26		
14 Feb 89	27		
15 Feb 89	28	2600.0	52.7
16 Feb 89	29		
17 Feb 89	30		
18 Feb 89	31		
19 Feb 89	32		
20 Feb 89	33		
21 Feb 89	34		
22 Feb 89	35	2636.0	24.8
23 Feb 89	36		
24 Feb 89	37		

(Continued)

* Electricity off.

C15

| | | BOD mg/l | |
DATE	DAY	INFLUENT	EFFLUENT
25 Feb 89	38		
26 Feb 89	39		
27 Feb 89	40		
28 Feb 89	41		
1 Mar 89	42	2127.0	36.0
2 Mar 89	43		
3 Mar 89	44		
4 Mar 89	45		
5 Mar 89	46		
6 Mar 89	47		
7 Mar 89	48		
8 Mar 89*	49, 10g		
9 Mar 89	50, 10g		
10 Mar 89	51, 10g		
11 Mar 89	52, 5g		
12 Mar 89	53, 5g		
13 Mar 89	54, 5g		
14 Mar 89	55, 2g		
15 Mar 89	56, 2g	2067.0	44.7
16 Mar 89	57, 1g		
17 Mar 89	58, 1g	2449.5	57.2
18 Mar 89	59, 1g		
19 Mar 89	60, 1g		
20 Mar 89	61, .5g		
21 Mar 89	62, .5g		
22 Mar 89	63, .5g	2039.0	48.6
23 Mar 89	64, .5g		
24 Mar 89	65, .5g	2116.5	65.5
25 Mar 89	66, .5g		
26 Mar 89	67, .5g		
27 Mar 89	68		
28 Mar 89	69		
29 Mar 89	70		
30 Mar 89	71		
31 Mar 89	72		
1 Apr 89	73		
2 Apr 89	74		
3 Apr 89	75		
4 Apr 89	76	2110.0	59.4
5 Apr 89	77		
6 Apr 89	78		
7 Apr 89	79	1803.6	59.7
8 Apr 89	80		

(Continued)

* Super Cee added.

| DATE | DAY | BOD mg/l | |
		INFLUENT	EFFLUENT
9 Apr 89	81		
10 Apr 89	82		
11 Apr 89	83		
12 Apr 89	84	2171.2	72.0
13 Apr 89	85		
14 Apr 89	86	1797.6	73.9
15 Apr 89	87		
16 Apr 89	88		
17 Apr 89	89		
18 Apr 89	90		
19 Apr 89	91	2129.0	53.4
20 Apr 89	92		
21 Apr 89	93	1908.0	45.8
22 Apr 89	94		
23 Apr 89	95		
24 Apr 89	96		
25 Apr 89	97		
26 Apr 89	98	2122.8	47.1
27 Apr 89	99		
28 Apr 89	100	1891.2	31.0
29 Apr 89	101		
30 Apr 89	102		
1 May 89	103		
2 May 89	104		
3 May 89	105	1908.2	28.5
4 May 89	106		
5 May 89	107	1888.2	35.8
6 May 89	108		
7 May 89	109		
8 May 89	110		
9 May 89	111		
10 May 89	112		
AVERAGE		1699.8	40.4
STANDARD DEVIATION		701.6	18.6
PERCENT REDUCTION			97.62

APPENDIX D: UNREDUCED DATA FOR TRANSITIONAL PHASE

Table D1

Transitional Phase

Temperature Data

DATE	DAY	REACTOR				
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL
11 May 89	1	17	18	18	17	17
12 May 89	2	16	17	17	16	17
13 May 89	3	19	20	20	19	20
14 May 89	4	20	19	21	20	21
15 May 89	5	23	23	23	23	21
16 May 89	6	20	20	20	20	19
17 May 89	7	21	21	21	21	21
18 May 89	8	21	21	21	21	21
19 May 89	9	21	21	21	21	21
20 May 89	10	20	21	21	20	20
21 May 89	11	20	20	19	20	19
22 May 89	12	19	19	18	19	18
23 May 89	13	20	20	19	19	19
24 May 89	14	20	20	21	21	21
25 May 89	15	21	22	21	21	21
26 May 89	16	19	19	19	19	19
27 May 89	17	18	18	17	17	
28 May 89	18	19	20	19	19	
29 May 89	19	19	19	19	19	
30 May 89	20	17	17	18	18	
31 May 89	21	20	20	20	20	
1 June 89	22	20	20	20	20	
2 June 89	23	20	20	20	20	
3 June 89	24	20	19	20	20	
4 June 89	25	21	20	20	20	
5 June 89	26	20	20	20	20	
6 June 89	27	20	19	19	19	
7 June 89	28	19	19	20	20	
8 June 89	29	19	19	19	18	
9 June 89	30	19	19	19	18	
10 June 89	31	20	20	19	19	
11 June 89	32	20	20	21	21	
12 June 89	33	20	20	20	19	
13 June 89	34	23	23	22	22	
14 June 89	35	20	20	20	20	
15 June 89	36	19	19	19	19	

(Continued)

DATE	DAY	REACTOR				
		TEMPERATURE Celsius				
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL
16 June 89	37	19	19	19	19	
17 June 89	38	21	22	22	21	
18 June 89	39	21	22	21	21	
19 June 89	40	21	22	21	21	
20 June 89	41	19	19	19	19	
21 June 89	42	19	20	19	19	
22 June 89	43	20	20	20	20	
23 June 89	44	22	22	22	22	
24 June 89	45	21	21	20	20	
25 June 89	46	20	20	20	20	
26 June 89	47	19	19	20	20	
27 June 89	48	19	19	19	19	
28 June 89	49	20	20	20	20	
29 June 89	50	19	19	19	19	
30 June 89	51	20	20	20	20	
1 July 89	52	20	20	20	20	
2 July 89	53	20	20	20	20	
3 July 89	54	20	20	20	20	
4 July 89	55	19	20	19	19	
5 July 89	56	20	20	20	20	
6 July 89	57	20	20	20	20	
7 July 89	58	20	20	20	20	
8 July 89	59	22	21	21	20	
9 July 89	60	20	21	20	20	
10 July 89	61	19	19	19	19	
11 July 89	62	19	19	19	19	
12 July 89	63	20	20	20	20	
13 July 89	64	20	20	20	20	
14 July 89	65	19	20	19	20	
15 July 89	66	20	20	20	20	
16 July 89	67	20	20	20	20	
17 July 89	68	19	19	19	20	
18 July 89	69	19	19	19	19	
19 July 89	70	19	19	19	19	
20 July 89	71	20	20	20	20	
21 July 89	72	20	20	20	20	
22 July 89	73	20	20	20	20	
23 July 89	74	22	22	22	22	
24 July 89	75	20	20	20	20	

(Continued)

Table D1 (Concluded)

DATE	DAY	TEMPERATURE Celsius				
		REACTOR				
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL
25 July 89	76	19	19	19	19	
26 July 89	77	19	19	19	19	
27 July 89	78	18	19	19	18	
28 July 89	79	19	20	19	19	
29 July 89	80	20	20	21	21	
30 July 89	81	20	20	20	20	
31 July 89	82	19	19	19	19	
1 Aug 89	83	20	20	20	20	
2 Aug 89	84	19	19	19	19	
3 Aug 89	85	19	19	19	19	
4 Aug 89	86	19	20	19	19	
5 Aug 89	87	19	19	20	19	
6 Aug 89	88	20	20	20	20	
AVERAGE		19.7	19.9	19.8	19.7	19.7
STANDARD DEVIATION		1.1	1.1	1.0	1.1	1.4

Table D2

Transitional Phase

Dissolved Oxygen and pH Data

DATE	DAY	DISSOLVED OXYGEN mg/l				pH
		REACTOR				
		2 DAY	4 DAY	8 DAY	16 DAY	INFLUENT
11 May 89	1	3.5	4.9	2.0	4.4	6.71
12 May 89	2	3.7	5.4	2.7	6.1	6.80
13 May 89	3					
14 May 89	4					
15 May 89	5	2.6	5.4	4.8	5.4	6.70
16 May 89	6	2.9	5.3	1.5	6.2	6.74
17 May 89	7	3.1	4.1	0.7	5.2	6.70
18 May 89	8	0.9	2.8	0.3	4.6	6.74
19 May 89	9	1.3	3.9	0.6	3.1	6.72
20 May 89	10	3.3	3.1	2.5	4.0	
21 May 89	11	2.2	3.2	2.4	3.0	
22 May 89	12	3.4	4.3	3.4	4.4	6.75
23 May 89	13	3.2	3.4	2.7	3.7	6.86
24 May 89	14	2.7	3.1	3.1	3.3	6.84
25 May 89	15	2.3	2.3	2.5	2.7	6.88
26 May 89	16	2.5	2.9	3.0	2.2	6.84
27 May 89	17	1.8	3.2	1.8	1.6	
28 May 89	18	2.7	2.6	2.5	0.6	
29 May 89	19	3.2	3.7	3.8	2.6	
30 May 89	20					6.78
31 May 89	21	5.8	6.2	5.7	6.0	6.75
1 June 89	22	5.4	4.7	4.0	4.6	6.79
2 June 89	23	5.6	5.2	5.4	7.5	6.84
3 June 89	24	6.0	6.4	6.4	6.0	
4 June 89	25	4.6	5.8	5.2	3.7	
5 June 89	26	3.7	4.7	3.4	4.4	6.75
6 June 89	27	6.3	5.1	4.4	5.1	7.17
7 June 89	28	4.4	5.7	4.2	4.9	7.13
8 June 89	29	3.5	3.8	3.5	2.3	6.69
9 June 89	30	3.5	3.5	3.0	3.7	
10 June 89	31	2.8	1.9	2.5	2.9	
11 June 89	32	2.0	4.5	3.4	2.6	
12 June 89	33					6.68
13 June 89	34	4.7	4.8	5.8	6.0	6.92
14 June 89	35	5.5	6.2	5.8	6.2	6.82
15 June 89	36	4.2	5.8	6.2	6.9	6.81

(Continued)

DATE	DAY	DISSOLVED OXYGEN mg/l				pH

REACTOR

		2 DAY	4 DAY	8 DAY	16 DAY	INFLUENT
16 June 89	37	6.2	6.6	7.1	7.4	6.85
17 June 89	38	4.3	3.5	3.0	4.4	
18 June 89	39	2.0	2.7	3.7	5.2	
19 June 89	40	2.1	4.9	4.4	4.8	6.90
20 June 89	41	2.3	2.2	3.2	3.8	6.97
21 June 89	42	2.2	2.1	2.4	2.3	7.07
22 June 89	43	6.4	7.3	6.9	7.4	
23 June 89	44	2.6	2.7	2.9	3.3	
24 June 89	45	2.3	3.1	4.6	4.8	
25 June 89	46	6.1	5.7	6.1	6.3	
26 June 89	47	3.8	3.5	3.4	4.1	
27 June 89	48	4.3	4.1	4.5	4.1	7.03
28 June 89	49	3.7	4.0	5.7	3.6	7.15
29 June 89	50	4.6	4.8	5.8	4.5	7.37
30 June 89	51					7.40
1 July 89	52	4.1	3.9	4.5	4.4	
2 July 89	53	3.8	3.7	4.0	3.7	
3 July 89	54	7.1	7.4	7.3	7.5	
4 July 89	55	6.5	7.2	7.5	7.8	
5 July 89	56	7.5	7.7	7.8	7.8	
6 July 89	57	7.4	7.2	7.3		6.69
7 July 89	58	7.5	7.4	7.2	7.5	
8 July 89	59	5.2	6.0	6.5	6.8	
9 July 89	60	6.4	6.4	6.4	6.5	
10 July 89	61	6.0	6.2	6.1	6.1	7.08
11 July 89	62	6.2	6.0	5.5	5.7	
12 July 89	63	5.7	5.7	5.4	5.7	6.92
13 July 89	64	5.4	5.5	5.3	5.6	
14 July 89	65	5.5	5.8	5.2	5.4	
15 July 89	66	5.4	5.5	5.5	5.5	
16 July 89	67	4.4	5.0	3.9	4.8	
17 July 89	68	7.8	6.4	7.1	5.7	6.85
18 July 89	69	6.3	6.1	6.2	5.1	6.82
19 July 89	70	5.5	6.0	5.5	5.4	6.80
20 July 89	71	4.0	4.0	4.1	3.8	6.82
21 July 89	72	4.5	4.4	4.5	4.4	6.80
22 July 89	73	2.5	3.5	2.4	2.4	
23 July 89	74	1.0	1.5	1.3	1.5	
24 July 89	75	8.1	8.2	7.1	7.8	6.74

(Continued)

Table D2 (Concluded)

DATE	DAY	DISSOLVED OXYGEN mg/l				pH
		REACTOR				
		2 DAY	4 DAY	8 DAY	16 DAY	INFLUENT
25 July 89	76	7.8	7.6	7.4	7.2	6.87
26 July 89	77	7.0	7.1	6.7	6.6	6.88
27 July 89	78	6.2	5.2	6.1	5.9	6.86
28 July 89	79	6.5	6.6	6.6	5.9	6.78
29 July 89	80	4.8	4.3	4.2	3.2	
30 July 89	81	3.8	3.5	3.2	3.3	
31 July 89	82	3.5	3.0	2.8	2.9	6.87
1 Aug 89	83	6.2	8.4	8.2	8.1	6.97
2 Aug 89	84	6.8	7.4	8.0	6.6	6.88
3 Aug 89	85	5.2	6.1	5.7	5.2	6.84
4 Aug 89	86	5.4	5.9	5.1	4.9	6.87
5 Aug 89	87	5.3	8.2	7.5	5.5	
6 Aug 89	88	5.5	8.0	7.9	5.6	
AVERAGE		4.5	5.0	4.6	4.9	6.87
STANDARD DEVIATION		1.8	1.7	1.9	1.7	0.16

Table D3

Transitional Phase

Salinity Data

DATE	DAY	SALINITY parts/thousand					
		REACTOR					
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL	INFLUENT
11 May 89	1	2.00	2.00	2.00	2.00	2.50	3.00
12 May 89	2	2.25	2.25	2.25	2.25	2.25	2.75
13 May 89	3						
14 May 89	4						
15 May 89	5	2.25	2.25	2.25	2.50	2.00	2.50
16 May 89	6	2.00	2.00	2.00	2.00	2.00	2.25
17 May 89	7	1.75	1.50	1.75	1.50	1.50	2.25
18 May 89	8	1.75	1.75	1.75	1.50	1.75	2.00
19 May 89	9	1.50	1.50	1.50	1.25	1.75	2.25
20 May 89	10						
21 May 89	11						
22 May 89	12	1.50	1.25	1.50	1.00	1.75	2.75
23 May 89	13	1.75	1.50	1.50	1.50	1.80	2.50
24 May 89	14	1.75	1.75	1.50	1.75	2.00	2.50
25 May 89	15	1.75	1.50	2.00	1.50		2.50
26 May 89	16	1.75	1.50	1.75	1.75		2.50
27 May 89	17						
28 May 89	18						
29 May 89	19						
30 May 89	20	1.25	1.25	1.50	1.50		2.25
31 May 89	21	1.75	1.50	1.75	1.75		2.80
1 June 89	22	1.50	1.50	1.50	1.50		2.25
2 June 89	23	1.50	1.50	1.50	1.50		2.00
3 June 89	24						
4 June 89	25						
5 June 89	26	1.50	1.50	1.50	1.75		2.20
6 June 89	27	1.50	1.50	1.50	1.50		2.00
7 June 89	28	1.50	1.50	1.50	1.50		2.00
8 June 89	29	1.50	1.50	1.50	1.50		2.00
9 June 89	30	1.75	1.75	1.75	1.70		2.00
10 June 89	31						
1 June 89	32						
12 June 89	33	1.50	1.50	1.75	2.00		3.00
13 June 89	34	1.75	1.50	1.50	2.00		3.00
14 June 89	35	1.75	1.50	1.25	2.00		1.50
15 June 89	36	1.50	1.50	1.50	1.75		3.00

(Continued)

DATE	DAY	REACTOR					
		SALINITY parts/thousand					
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL	INFLUENT
16 June 89	37	2.00	1.50	1.50	2.00		3.00
17 June 89	38						
18 June 89	39						
19 June 89	40	1.50	1.50	1.50	1.50		2.50
20 June 89	41	1.50	1.50	1.50	1.50		2.50
21 June 89	42	1.50	1.50	1.50	1.50		2.50
22 June 89	43	1.50	1.50	1.50	1.50		2.25
23 June 89	44						
24 June 89	45						
25 June 89	46						
26 June 89	47	1.50	1.50	1.50	1.50		2.25
27 June 89	48	1.50	1.50	1.50	1.50		2.20
28 June 89	49	1.50	1.50	1.50	1.50		2.25
29 June 89	50	1.00	1.50	1.50	1.50		2.25
30 June 89	51						
1 July 89	52						
2 July 89	53						
3 July 89	54	2.50	1.50	1.50	1.50		2.25
4 July 89	55						
5 July 89	56	1.50	1.50	1.50	1.50		2.20
6 July 89	57	1.50	1.50	1.50	1.50		1.75
7 July 89	58	1.50	1.50	1.50	1.50		1.75
8 July 89	59						
9 July 89	60						
10 July 89	61						
11 July 89	62	1.30	0.30	1.00	1.00		
12 July 89	63	1.00	1.00	1.00	1.00		1.75
13 July 89	64						
14 July 89	65	1.00	1.00	1.00	0.75		
15 July 89	66						
16 July 89	67						
17 July 89	68	1.50	1.25	1.25	1.25		2.50
18 July 89	69	1.25	1.25	1.25	1.25		2.75
19 July 89	70	1.25	1.25	1.50	1.25		2.70
20 July 89	71	1.25	1.50	1.50	1.50		2.50
21 July 89	72	1.50	1.50	1.50	1.50		2.50
22 July 89	73						
23 July 89	74						
24 July 89	75	1.50	1.50	1.50	1.50		2.50

(Continued)

Table D3 (Concluded)

DATE	DAY	SALINITY parts/thousand					
		REACTOR					
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL	INFLUENT
25 July 89	76	1.50	1.50	1.50	1.50		2.50
26 July 89	77	1.25	1.25	1.50	1.50		2.50
27 July 89	78	1.50	1.50	1.50	1.50		2.25
28 July 89	79	1.20	1.50	1.20	1.30		2.20
29 July 89	80						
30 July 89	81						
31 July 89	82	1.75	1.50	1.50	1.50		2.5
1 Aug 89	83	1.75	1.50	1.75	1.75		2.5
2 Aug 89	84	1.50	1.30	1.40	1.50		2.5
3 Aug 89	85	1.90	1.50	1.90	1.50		2.5
4 Aug 89	86	1.50	1.50	1.50	1.50		2.5
5 Aug 89	87						
6 Aug 89	88						
AVERAGE		1.57	1.49	1.54	1.55		2.38
STANDARD DEVIATION		0.29	0.27	0.25	0.30		0.33

Table D4

Transitional Phase

Conductivity Data

DATE	DAY	CONDUCTIVITY micromhos/cm

DATE	DAY	REACTOR		
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL	INFLUENT
11 May 89	1	3200	3100	3200	3150	3750	4700
12 May 89	2	3300	3250	3350	3300	3450	4100
13 May 89	3						
14 May 89	4						
15 May 89	5	3600	3700	3750	3750	3350	4050
16 May 89	6	3450	3250	3450	3250	3550	3900
17 May 89	7	3100	2700	2950	2600	2850	4050
18 May 89	8	3000	2800	2950	2600	3100	3900
19 May 89	9	2800	2600	2800	2300	3050	4000
20 May 89	10						
21 May 89	11						
22 May 89	12	2450	2100	2550	1950	3100	4350
23 May 89	13	2600	2300	2500	2500	2850	3850
24 May 89	14	2600	2500	2350	2500	3300	3900
25 May 89	15	2600	2700	2600	2600		3875
26 May 89	16	2600	2200	2500	2500		3880
27 May 89	17						
28 May 89	18						
29 May 89	19						
30 May 89	20	2200	2100	2500	2550		3700
31 May 89	21	2550	2450	2500	2600		4300
1 June 89	22	2550	2550	2500	2300		3885
2 June 89	23	2450	2400	2500	2450		3300
3 June 89	24						
4 June 89	25						
5 June 89	26	2650	2400	2500	2700		3600
6 June 89	27	2300	2300	2400	2450		3150
7 June 89	28	2400	2400	2500	2500		3100
8 June 89	29	2500	2400	2500	2500		3400
9 June 89	30	2550	2600	2550	2500		3250
10 June 89	31						
11 June 89	32						
12 June 89	33	2450	2200	2350	2900		4100
13 June 89	34	2650	2300	2200	2700		3700
14 June 89	35	2500	2200	2150	2600		2150

(Continued)

D12

DATE	DAY	CONDUCTIVITY micromhos/cm					
		REACTOR					
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL	INFLUENT
15 June 89	36	2250	2200	2250	2650		4100
16 June 89	37	2550	2100	2150	2650		4100
17 June 89	38						
18 June 89	39						
19 June 89	40	2600	2350	2550	2500		3250
20 June 89	41	2450	2350	2400	2400		3000
21 June 89	42	2350	2200	2350	2500		2500
22 June 89	43	2450	2400	2500	2400		3500
23 June 89	44						
24 June 89	45						
25 June 89	46						
26 June 89	47	2400	2450	2400	2500		3250
27 June 89	48	2500	2300	2500	2500		3150
28 June 89	49	2450	2400	2500	2400		3450
29 June 89	50	2000	2500	2500	1900		3250
30 June 89	51						
1 July 89	52						
2 July 89	53						
3 July 89	54	2650	2500	2500	2600		3500
4 July 89	55						
5 July 89	56	2650	2500	2500	2450		3300
6 July 89	57	2750	2400	2750	2750		2650
7 July 89	58	2450	2300	2300	2300		2750
8 July 89	59						
9 July 89	60						
10 July 89	61						
11 July 89	62	1900	2200	1650	1550		
12 July 89	63	1900	2100	1800	1400		2300
13 July 89	64						
14 July 89	65	1800	1800	1650	1250		
15 July 89	66						
16 July 89	67						
17 July 89	68	2150	2100	2150	2050		3850
18 July 89	69	2250	2300	2300	2250		3900
19 July 89	70	2250	2250	2600	2450		3950
20 July 89	71	2000	2250	2600	2450		3850
21 July 89	72	2300	2400	2100	2420		3700
22 July 89	73						
23 July 89	74						

(Continued)

DATE	DAY	CONDUCTIVITY micromhos/cm					

REACTOR

DATE	DAY	2 DAY	4 DAY	8 DAY	16 DAY	CONTROL	INFLUENT
24 July 89	75	2550	2450	2600	2500		3800
25 July 89	76	2600	2450	2350	2500		3500
26 July 89	77	2550	2100	2600	2600		3800
27 July 89	78	2550	2500	2600	2600		3800
28 July 89	79	2250	2400	2000	2100		3350
29 July 89	80						
30 July 89	81						
31 July 89	82	2500	2500	2600	2550		3900
1 Aug 89	83	2700	2450	2500	2650		3700
2 Aug 89	84	2600	2500	2500	2600		3700
3 Aug 89	85	2550	2500	2550	2500		3500
4 Aug 89	86	2400	2400	2500	2500		3200
5 Aug 89	87						
6 Aug 89	88						
AVERAGE		524.11	2430.36	2498.21	2485.18	3235.00	3587.78
STANDARD DEVIATION		341.08	309.33	363.02	391.23	282.00	502.26

APPENDIX E: UNREDUCED DATA FOR ACTIVATED SLUDGE STUDY

Table E1
Activated Sludge Study
Temperature Data

DATE	DAY	TEMPERATURE Celsius				
		REACTOR				
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL
7 Aug	1	19	19	19	19	19
8 Aug	2	17	17	17	17	17
9 Aug	3	17	17	18	18	18
10 Aug	4	19	19	19	19	19
11 Aug	5	19	19	19	19	19
12 Aug	6	19	20	20	20	19
13 Aug	7	21	21	21	20	20
14 Aug	8	19	19	19	19	19
15 Aug	9	20	20	20	20	20
16 Aug	10	19	19	19	19	19
17 Aug	11	18	18	18	18	18
18 Aug	12	20	20	21	20	21
19 Aug	13	20	20	19	20	20
20 Aug	14	20	20	20	20	19
21 Aug	15	20	20	19	20	19
22 Aug	16	20	20	20	20	20
23 Aug	17	20	20	20	20	21
24 Aug	18	20	20	20	20	21
25 Aug	19	22	22	21	22	25
26 Aug	20	20	20	20	20	21
27 Aug	21	21	20	20	21	21
28 Aug	22	20	20	20	20	21
29 Aug	23	20	20	20	20	20
30 Aug	24	20	20	20	20	20
31 Aug	25	20	20	20	21	21
1 Sept	26	20	20	20	19	20
2 Sept	27	20	20	20	20	21
3 Sept	28	20	20	20	20	20
4 Sept	29	20	20	20	19	20
5 Sept	30	20	20	20	20	21
6 Sept	31	20	20	20	19	20
7 Sept	32	21	21	20	21	22
8 Sept	33	21	22	21	21	23
9 Sept	34	20	20	20	20	20
10 Sept	35	20	20	20	21	21
11 Sept	36	19	19	19	20	20
12 Sept	37	20	20	20	20	20
13 Sept	38	20	20	20	20	20
14 Sept	39	21	21	21	21	21

(Continued)

E3

Table E1 (Concluded)

DATE	DAY	TEMPERATURE Celsius				
				REACTOR		
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL
15 Sept	40	19	19	19	19	19
16 Sept	41	20	20	20	19	19
17 Sept	42	20	20	20	19	20
18 Sept	43	19	20	20	19	20
19 Sept	44	21	21	20	21	21
AVERAGE		20	20	20	20	20
STANDARD DEVIATION		0.943	0.952	0.801	0.926	1.318

Table E2

Activated Sludge Study

Dissolved Oxygen Data

DATE	DAY	DISSOLVED OXYGEN mg/l			
		REACTOR			
		2 DAY	4 DAY	8 DAY	16 DAY
7 Aug	1	5.0	6.5	5.1	5.3
8 Aug	2	5.6	6.8	5.9	5.6
9 Aug	3	4.1	4.8	4.6	3.8
10 Aug	4	3.3	3.6	3.2	3.2
11 Aug	5	2.0	1.8	2.3	2.0
12 Aug	6				
13 Aug	7				
14 Aug	8				
15 Aug	9				
16 Aug	10	6.1	6.5	5.5	5.4
17 Aug	11	6.2	6.7	6.0	6.4
18 Aug	12	5.8	6.6	6.1	6.5
19 Aug	13				
20 Aug	12				
21 Aug	15	6.3	5.4	6.0	5.5
22 Aug	16	4.0	3.3	4.5	5.5
23 Aug	17	6.0	5.8	6.5	7.4
24 Aug	18	5.3	5.1	5.2	6.8
25 Aug	19	5.3	5.6	5.4	5.8
26 Aug	20				
27 Aug	21				
28 Aug	22	7.5	5.9	7.2	7.3
29 Aug	23	4.0	5.3	6.4	6.2
30 Aug	24	5.2	4.3	6.0	6.3
31 Aug	25	3.5	2.7	2.5	2.7
1 Sept	26	3.6	3.0	2.7	3.2
2 Sept	27				
3 Sept	28				
4 Sept	29				
5 Sept	30	8.0	7.5	6.8	6.2
6 Sept	31	6.2	6.5	5.6	6.0
7 Sept	32	7.4	6.5	6.9	7.0
8 Sept	33	6.6	6.2	6.9	5.8
9 Sept	34				
10 Sept	35				
11 Sept	36	7.8	7.4	7.6	6.9
12 Sept	37	7.4	7.0	7.8	7.2
13 Sept	38	8.2	7.0	8.0	6.8

(Continued)

E5

Table E2 (Concluded)

DATE	DAY	DISSOLVED OXYGEN mg/l			
		REACTOR			
		2 DAY	4 DAY	8 DAY	16 DAY
14 Sept	39	7.8	6.4	6.5	5.6
15 Sept	40	5.2	5.2	5.0	5.3
16 Sept	41				
17 Sept	42				
18 Sept	43	7.5	6.9	7.1	7.6
19 Sept	44	6.4	6.6	6.7	7.0
AVERAGE		5.8	5.6	5.7	5.7
STANDARD DEVIATION		1.59	1.48	1.51	1.44

Table E3

Activated Sludge Study

Salinity Data

DATE	DAY	SALINITY parts/thousand					
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL	INFLUENT
7 Aug	1	1.5	1.3	1.7	1.5	2.5	2.5
8 Aug	2	2.8	1.2	2.0	2.0	1.5	2.5
9 Aug	3	2.0	1.8	1.8	1.9	2.0	3.0
10 Aug	4	1.5	2.0	1.5	1.5	1.8	3.0
11 Aug	5	1.8	1.5	1.8	1.8	1.5	3.0
12 Aug	6						
13 Aug	7						
14 Aug	8	2.0	1.5	1.8	1.8	1.8	2.8
15 Aug	9	1.8	1.5	1.5	2.0	1.8	3.0
16 Aug	10	2.3	1.8	1.8	2.0	2.0	3.0
17 Aug	11	2.0	1.8	2.0	1.8	2.0	3.0
18 Aug	12	2.0	1.8	1.8	1.8	2.0	3.0
19 Aug	13						
20 Aug	14						
21 Aug	15	1.5	1.5	2.0	2.0	2.5	3.0
22 Aug	16	2.0	2.0	2.0	2.0	2.3	3.0
23 Aug	17	1.5	1.5	2.0	2.0	2.5	3.0
24 Aug	18	2.0	2.0	2.0	2.0	2.5	3.0
25 Aug	19	2.0	2.0	2.1	2.1	2.0	3.0
26 Aug	20						
27 Aug	21						
28 Aug	22	2.0	1.9	1.5	1.5	1.5	3.0
29 Aug	23	1.9	1.5	1.5	1.7	2.5	3.0
30 Aug	24	2.0	1.5	1.9	2.0	2.0	2.9
31 Aug	25	1.2	2.0	2.0	2.0	2.5	3.0
1 Sept	26	2.0	1.9	1.9	1.9	2.0	3.0
2 Sept	27						
3 Sept	28						
4 Sept	29						
5 Sept	30						
6 Sept	31	2.0	1.5	1.5	1.5	2.5	3.0
7 Sept	32	1.9	1.5	1.9	1.5		2.0
8 Sept	33	2.0	1.5	1.5	1.5		3.0
9 Sept	34						
10 Sept	35						
11 Sept	36	1.5	1.5	1.5	1.5		2.9
12 Sept	37	1.9	1.5	1.5	1.9		2.9
13 Sept	38	1.5	1.5	1.5	1.5		2.9
14 Sept	39	1.5	1.5	1.5	1.9		3.0

(Continued)

E7

Table E3 (Concluded)

DATE	DAY	SALINITY parts/thousand					
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL	INFLUENT
15 Sept	40	2.0	1.5	1.5	1.9		3.0
16 Sept	41						
17 Sept	42						
18 Sept	43	1.6	1.8	1.5	1.5		3.0
19 Sept	44	1.8	2.0	1.5	2.0		3.0
AVERAGE		1.8	1.7	1.7	1.8	2.1	2.9
STANDARD DEVIATION		0.30	0.23	0.22	0.21	0.35	0.21

Table E4

Activated Sludge Study

Conductivity Data

DATE	DAY	CONDUCTIVITY micromhos/cm					
		REACTOR				CONTROL	INFLUENT
		2 DAY	4 DAY	8 DAY	16 DAY		
7 Aug	1	2800	2650	2750	2250	4200	3550
8 Aug	2	3000	2400	2400	2320	2400	4010
9 Aug	3	3100	2700	2800	2950	2950	4000
10 Aug	4	2700	2700	2900	2900	2850	3530
11 Aug	5	2850	2500	2900	2800	2700	4220
12 Aug	6						
13 Aug	7						
14 Aug	8	3050	2450	2650	2900	2900	3850
15 Aug	9	2800	2500	2800	3000	2900	3850
16 Aug	10	3400	2900	2900	3100	3200	4400
17 Aug	11	3000	2750	3000	2900	3000	4100
18 Aug	12	2950	2650	2600	2750	3050	3950
19 Aug	13						
20 Aug	14	.					
21 Aug	15	1800	2950	3100	3050	3300	4900
22 Aug	16	3150	3100	3100	2900	3400	4800
23 Aug	17	3100	3000	3100	2900	3300	4700
24 Aug	18	3200	3150	2750	2900	3400	4200
25 Aug	19	3000	3100	3000	2900	3350	4500
26 Aug	20						
27 Aug	21						
28 Aug	22	3100	2850	2800	2600	2850	3950
29 Aug	23	2900	2800	2830	2750	2900	3450
30 Aug	24	3250	2700	3000	3000	3250	3500
31 Aug	25	2000	3300	3200	3300	3500	4600
1 Sept	26	3000	2900	2900	3000	3300	4600
2 Sept	27						
3 Sept	28						
4 Sept	29						
5 Sept	30						
6 Sept	31	3000	2400	2850	2550		4000
7 Sept	32	2900	2600	3050	2900		4000
8 Sept	33	3200	2650	2700	2800		4900
9 Sept	34						
10 Sept	35						
11 Sept	36	2800	2400	2600	2700		4500
12 Sept	37	3000	2500	2500	2900		3900
13 Sept	38	2600	2700	2650	2600		4700
14 Sept	39	2900	2750	3050	2950		4000

(Continued)

E9

Table E4 (Concluded)

DATE	DAY	REACTOR				CONTROL	INFLUENT
		2 DAY	4 DAY	8 DAY	16 DAY		
15 Sept	40	3100	2650	2800	2900		4300
16 Sept	41						
17 Sept	42						
18 Sept	43	2700	2550	2600	2900		4700
19 Sept	44	3000	2500	2600	2950		4200
AVERAGE		2912	2725	2829	2844	3135	4195
STANDARD DEVIATION		320.85	235.85	196.86	210.74	365.41	417.52

The conductivity heading spans the reactor, control, and influent columns:

CONDUCTIVITY
micromhos/cm

Table E5

Activated Sludge Study

Sludge Volume Index Data

DATE	DAY	SLUDGE VOLUME INDEX mg/l			
		2 DAY	4 DAY	8 DAY	16 DAY
7 Aug	1	8.2	8.0	10.9	4.9
8 Aug	2	8.9	6.2	7.2	5.9
9 Aug	3	8.2	7.6	7.4	6.3
10 Aug	4	8.2	5.0	7.4	4.4
11 Aug	5	8.2	5.0	11.9	5.0
12 Aug	6				
13 Aug	7				
14 Aug	8	7.6	6.8	7.3	5.3
15 Aug	9	8.7	6.6	5.0	4.8
16 Aug	10	8.7	6.6	5.0	4.2
17 Aug	11	5.7	6.0	7.9	3.6
18 Aug	12	5.7	6.0	4.8	3.0
19 Aug	13				
20 Aug	14				
21 Aug	15				
22 Aug	16	5.2	3.4	5.2	1.8
23 Aug	17				
24 Aug	18	5.0	3.3	6.0	3.0
25 Aug	19				
26 Aug	20				
27 Aug	21				
28 Aug	22				
29 Aug	23	4.2	1.6	4.6	2.8
30 Aug	24				
31 Aug	25				
1 Sept	26	3.0	2.7	4.0	1.2
2 Sept	27				
3 Sept	28				
4 Sept	29				
5 Sept	30				
6 Sept	31	5.5	3.1	6.6	3.5
7 Sept	32	8.4	1.9	3.4	10.6
8 Sept	33				
9 Sept	34				
10 Sept	35				
11 Sept	36				
12 Sept	37	4.4	1.3	2.3	2.0
13 Sept	38				
14 Sept	39	4.5	2.5	2.1	2.0

(Continued)

Table E5 (Concluded)

DATE	DAY	SLUDGE VOLUME INDEX mg/l			
		2 DAY	4 DAY	8 DAY	16 DAY
15 Sept	40				
16 Sept	41				
17 Sept	42				
18 Sept	43				
19 Sept	44	7.1	3.3	3.0	2.5
AVERAGE		6.60	4.57	5.89	4.04
STANDARD DEVIATION		1.84	2.08	2.56	2.10

Table E6

Activated Sludge Study

Suspended Solids Data

DATE	DAY	SUSPENDED SOLIDS mg/l				
		REACTOR				
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL
7 Aug	1	2440	3740	5033	16080	˙
8 Aug	2	1373	3240	6926	11866	373
9 Aug	3					
10 Aug	4	2426	3973	6740	15953	93.3
11 Aug	5					
12 Aug	6					
13 Aug	7					
14 Aug	8	2620	2920	8233	17000	266.6
15 Aug	9	2300	3027	9953	16686	853.3
16 Aug	10					
17 Aug	11	3533	3307	3687	19767	820
18 Aug	12					
19 Aug	13					
20 Aug	14					
21 Aug	15					
22 Aug	16	3840	5413	5720	22407	5353
23 Aug	17					
24 Aug	18	4067	6093	6780	16573	7040
25 Aug	19					
26 Aug	20					
27 Aug	21					
28 Aug	22					
29 Aug	23	2387	9433	6567	14820	2973
30 Aug	24					
31 Aug	25					
1 Sept	26	3453	7573	7327	34350	7587
2 Sept	27					
3 Sept	28					
4 Sept	29					
5 Sept	30					
6 Sept	31	1827	3227	6020	11447	880
7 Sept	32	3560	5253	8747	7580	473
8 Sept	33					
9 Sept	34					
10 Sept	35					
11 Sept	36					
12 Sept	37	2273	7547	8387	15333	500
13 Sept	38					
14 Sept	39	2247	8173	14080	19767	2707

(Continued)

E13

Table E6 (Concluded)

DATE	DAY	SUSPENDED SOLIDS mg/l				
		REACTOR				
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL
15 Sept	40					
16 Sept	41					
17 Sept	42					
18 Sept	43					
19 Sept	44	1400	5987	6680	11907	3607
AVERAGE		2898	5784	8086	18390	2573
STANDARD DEVIATION		822.13	2068.53	2323.79	5923.93	2500.53

Table E7

Activated Sludge Study

Volatile Suspended Solids

DATE	DAY	VOLATILE SUSPENDED SOLIDS mg/l				
		REACTOR				
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL
7 Aug	1	1093	1480	1820	4540	
8 Aug	2	1040	1586	2533	3426	473
9 Aug	3					
10 Aug	4	1440	1853	2560	4773	580
11 Aug	5					
12 Aug	6					
13 Aug	7					
14 Aug	8	1400	1500	2773	4956	693
15 Aug	9	1367	1500	3220	4940	993
16 Aug	10					
17 Aug	11	1160	1173	1960	5227	580
18 Aug	12					
19 Aug	13					
20 Aug	14					
21 Aug	15					
22 Aug	16	1307	1627	1900	5680	2053
23 Aug	17					
24 Aug	18	1373	1907	2160	4460	2387
25 Aug	19					
26 Aug	20					
27 Aug	21					
28 Aug	22					
29 Aug	23	1033	2793	2300	4266	1507
30 Aug	24					
31 Aug	25					
1 Sept	26	1400	2440	2370	8450	2600
2 Sept	27					
3 Sept	28					
4 Sept	29					
5 Sept	30					
6 Sept	31	1167	1213	1933	3453	840
7 Sept	32	1360	1873	2520	2373	587
8 Sept	33					
9 Sept	34					
10 Sept	35					
11 Sept	36					
12 Sept	37	1067	2273	2393	4087	762
13 Sept	38					
14 Sept	39	960	2247	3847	5213	1380

(Continued)

Table E7 (Concluded)

DATE	DAY	VOLATILE SUSPENDED SOLIDS mg/l				
		REACTOR				
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL
15 Sept	40					
16 Sept	41					
17 Sept	42					
18 Sept	43					
19 Sept	44	773	2007	2307	3300	1580
AVERAGE		1196	1831	2440	4610	1134
STANDARD DEVIATION		192.78	444.42	517.34	1335.91	689.66

Table E8

Activated Sludge Study

Chemical Oxygen Demand Data

DATE	DAY	CHEMICAL OXYGEN DEMAND					
		REACTOR					
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL	INFLUENT
7 Aug	1						
8 Aug	2	1310	1170	947	1370	3180	
9 Aug	3						
10 Aug	4	1290	1240	1380	1320	1820	
11 Aug	5						
12 Aug	6						
13 Aug	7						
14 Aug	8						
15 Aug	9	1230	1140	1340	1290	1240	
16 Aug	10						
17 Aug	11	1160	1300	1340	1140	1370	
18 Aug	12						
19 Aug	13						
20 Aug	14						
21 Aug	15						
22 Aug	16	1220	1250	1310	1060	1210	
23 Aug	17						
24 Aug	18	1200	1240	1250	1300	1230	
25 Aug	19						
26 Aug	20						
27 Aug	21						
28 Aug	22						
29 Aug	23	1230	1250	1320	1190	1300	
30 Aug	24						
31 Aug	25	1310	1130	1240	1460	1330	3700
1 Sept	26						
2 Sept	27						
3 Sept	28						
4 Sept	29						
5 Sept	30	1430	1250	965	1330	1910	3740
6 Sept	31						
7 Sept	32	1610	1740	1260	1320	1370	3710
8 Sept	33						
9 Sept	34						
10 Sept	35						
11 Sept	36	1160	1210	5270	1090	1310	986
12 Sept	37						
13 Sept	38						
14 Sept	39	1100	1250	1690	1190	1260	3740

(Continued)

E17

Table E8 (Concluded)

DATE	DAY	CHEMICAL OXYGEN DEMAND					
		REACTOR					
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL	INFLUENT
15 Sept	40						
16 Sept	41						
17 Sept	42						
18 Sept	43	1130	1300	1170	1220		3800
19 Sept	44						
AVERAGE		1260.00	1266.92	1575.54	1252.31	1544.17	3279.33
Sd		132.08	145.73	1081.22	111.16	539.33	1026.10
% REDUCTION		61.58	61.37	51.96	61.81	52.91	

Table E9

Activated Sludge Study

Biochemical Oxygen Demand Data

| DATE | DAY | REACTOR | | | | | |
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL	INFLUENT
7 Aug	1						
8 Aug	2						
9 Aug	3	126.96	219.99	142.96	147.29		1774.40
10 Aug	4						
11 Aug	5	123.30	142.70	165.30	184.00	625.00	1985.00
12 Aug	6						
13 Aug	7						
14 Aug	8						
15 Aug	9						
16 Aug	10	116.13	109.13	154.47	137.80	136.00	1517.00
17 Aug	11						
18 Aug	12	79.16	108.83	97.83	109.83	117.40	1592.40
19 Aug	13						
20 Aug	14						
21 Aug	15						
22 Aug	16						
23 Aug	17	77.55	108.55	146.55	123.21	131.60	1728.20
24 Aug	18						
25 Aug	19	83.01	112.35	82.36	111.01	335.10	1670.40
26 Aug	20						
27 Aug	21						
28 Aug	22						
29 Aug	23						
30 Aug	24	181.16	118.83	191.16	161.16	166.24	1832.40
31 Aug	25						
1 Sept	26	228.00	109.00	128.39	133.05	182.08	2045.80
2 Sept	27						
3 Sept	28						
4 Sept	29						
5 Sept	30						
6 Sept	31	141.06	125.71	107.71	1325.71		1910.60
7 Sept	32						
8 Sept	33	128.00	123.66	67.33	91.33	1J7.00	1430.00
9 Sept	34						
10 Sept	35						
11 Sept	36						
12 Sept	37						
13 Sept	38	129.35	123.01	127.52	77.35	176.34	1710.20
14 Sept	39						

(Continued)

Table E9 (Concluded)

DATE	DAY	BIOCHEMICAL OXYGEN DEMAND mg/l					
		REACTOR					
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL	INFLUENT
15 Sept	40	95.33	131.00	150.33	67.00	134.66	1460.00
16 Sept	41						
17 Sept	42						
18 Sept	43						
19 Sept	44	79.43	169.09	140.43	109.43	179.14	1821.40
AVERAGE		122.19	130.91	130.95	213.71	208.23	1729.06
SD		42.16	30.52	33.14	322.53	144.32	185.91
% REDUCTION		92.93	92.43	92.43	87.64	87.96	

Table E10

Activated Sludge Study

Total Organic Carbon Data

DATE	DAY	TOTAL ORGANIC CARBON ppm					
		REACTOR					
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL	INFLUENT
7 Aug	1						
8 Aug	2	284	251	300	288	834	
9 Aug	3						
10 Aug	4	288	275	297	285	447	
11 Aug	5						
12 Aug	6						
13 Aug	7						
14 Aug	8						
15 Aug	9	291	290	321	318	291	
16 Aug	10						
17 Aug	11	282	264	333	264	287	
18 Aug	12						
19 Aug	13						
20 Aug	14						
21 Aug	15						
22 Aug	16	267	257	333	291	318	
23 Aug	17						
24 Aug	18	261	273	294	267	342	
25 Aug	19						
26 Aug	20						
27 Aug	21						
28 Aug	22						
29 Aug	23	423	228	290	240	300	786
30 Aug	24						
31 Aug	25	321	252	288	294	368	677
1 Sept	26						
2 Sept	27						
3 Sept	28						
4 Sept	29						
5 Sept	30	333	297	279	213	438	
6 Sept	31						
7 Sept	32	369	255	282	273	317	730
8 Sept	33						
9 Sept	34						
10 Sept	35						
11 Sept	36	258	273	273	246	264	756
12 Sept	37						
13 Sept	38						
14 Sept	39	237	269	294	267	339	725

(Continued)

E21

Table E10 (Concluded)

DATE	DAY	TOTAL ORGANIC CARBON ppm					
		REACTOR					
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL	INFLUENT
15 Sept	40						
16 Sept	41						
17 Sept	42						
18 Sept	43	306	264	270	282		795
19 Sept	44						
AVERAGE		301.50	265.05	296.42	271.38	378.67	744.67
SD		48.51	17.04	19.97	25.98	147.63	40.08
PERCENT REDUCTION		59.51	64.41	60.19	63.56	49.15	

Table F11

Activated Sludge Study

HNU Data

DATE	DAY	2 DAY	4 DAY	8 DAY	16 DAY	CONTROL	INFLUENT
				HNU READINGS			
7 Aug	1						
8 Aug	2						
9 Aug	3						
10 Aug	4	0.3	0.3	0.3	0.3	6	17
11 Aug	5						
12 Aug	6						
13 Aug	7						
14 Aug	8						
15 Aug	9						
16 Aug	10						
17 Aug	11						
18 Aug	12						
19 Aug	13						
20 Aug	14						
21 Aug	15						
22 Aug	16	0.2	0.2	0.2	0.2	0.3	25
23 Aug	17	0.2	0.2	0.3	0.2	0.4	20
24 Aug	18	0.1	0.1	0.1	0.1	0.2	25
25 Aug	19						
26 Aug	20						
27 Aug	21						
28 Aug	22						
29 Aug	23						
30 Aug	24	0.3	0.2	0.2	0.2	0.2	23
31 Aug	25						
1 Sept	26	0.2	0.2	0.2	0.2	0.3	25
2 Sept	27						
3 Sept	28						
4 Sept	29						
5 Sept	30						
6 Sept	31	0.2	0.2	0.2	0.2	0.2	72
7 Sept	32	0.1	0.1	0.1	0.1	0.3	30
8 Sept	33						
9 Sept	34						
10 Sept	35						
11 Sept	36	0.1	0.1	0.2	0.1	0.1	10
12 Sept	37						
13 Sept	38						
14 Sept	39	0.1	0.1	0.1	0.1		33

(Continued)

E23

DATE	DAY	HNU READINGS					
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL	INFLUENT
15 Sept	40						
16 Sept	41						
17 Sept	42						
18 Sept	43						
19 Sept	44	0.1	0.1	0.2	0.1		25
AVERAGE		0.2	0.2	0.2	0.2	0.9	21
STANDARD DEVIATION		0.07	0.06	0.07	0.06	1.81	8.90

Table E12

Activated Sludge Study

Reactor 1 Nutrient Data

DATE	DAY	NUTRIENTS					
		REACTOR 2 DAY					
		TKN	TP	OPO4	NO-2N	NO3-N	NH3-N
7 Aug	1						
8 Aug	2						
9 Aug	3						
10 Aug	4	75.0	15.30	7.14	<0.010	<0.050	6.02
11 Aug	5						
12 Aug	6						
13 Aug	7						
14 Aug	8						
15 Aug	9						
16 Aug	10						
17 Aug	11	73.2	11.60	5.93	<0.010	<0.050	8.62
18 Aug	12						
19 Aug	13						
20 Aug	14						
21 Aug	15						
22 Aug	16						
23 Aug	17						
24 Aug	18	74.8	12.60	4.58	<0.010	<0.050	9.05
25 Aug	19						
26 Aug	20						
27 Aug	21						
28 Aug	22						
29 Aug	23						
30 Aug	24						
31 Aug	25	77.8	11.50	7.50	<0.010	<0.050	12.40
1 Sept	26						
2 Sept	27						
3 Sept	28						
4 Sept	29						
5 Sept	30						
6 Sept	31						
7 Sept	32						
8 Sept	33						
9 Sept	34						
10 Sept	35						
11 Sept	36	38.0	8.96	5.73	0.011	0.018	13.40
12 Sept	37						
13 Sept	38						
14 Sept	39	79.6	14.80	6.42	0.018	<0.010	11.10

(Continued)

DATE	DAY	NUTRIENTS					
				REACTOR 2 DAY			
		TKN	TP	OPO4	NO-2N	NO3-N	NH3-N
15 Sept	40						
16 Sept	41						
17 Sept	42						
18 Sept	43						
19 Sept	44	64.0	11.00	5.97	0.026	<0.010	16.6
AVERAGE		68.9	12.3	6.2	0.018	0.003	11.0
STANDARD DEVIATION		13.43	2.05	0.89	0.01	0.01	3.24

Table E13

Activated Sludge Study

Reactor 2 Data

DATE	DAY	NUTRIENTS ppm					
		REACTOR 4 DAY					
		TKN	TP	OPO4	NO-2N	NO3-N	NH3-N
7 Aug	1						
8 Aug	2						
9 Aug	3						
10 Aug	4	79.0	13.0	5.29	<0.010	<0.050	7.78
11 Aug	5						
12 Aug	6						
13 Aug	7						
14 Aug	8						
15 Aug	9						
16 Aug	10						
17 Aug	11	78.4	11.4	5.11	<0.010	<0.050	8.98
18 Aug	12						
19 Aug	13						
20 Aug	14						
21 Aug	15						
22 Aug	16						
23 Aug	17						
24 Aug	18	78.2	11.1	5.93	<0.010	<0.050	14.10
25 Aug	19						
26 Aug	20						
27 Aug	21						
28 Aug	22						
29 Aug	23						
30 Aug	24						
31 Aug	25	78.2	10.2	4.30	<0.010	<0.050	12.70
1 Sept	26						
2 Sept	27						
3 Sept	28						
4 Sept	29						
5 Sept	30						
6 Sept	31						
7 Sept	32						
8 Sept	33						
9 Sept	34						
10 Sept	35						
11 Sept	36	75.2	11.6	4.33	0.024	<0.010	13.80
12 Sept	37						

(Continued)

Table E13 (Concluded)

DATE	DAY	NUTRIENTS ppm					
		REACTOR 4 DAY					
		TKN	TP	OPO4	NO-2N	NO3-N	NH3-N
13 Sept	38						
14 Sept	39	75.6	10.7	4.13	0.016	<0.010	13.20
15 Sept	40						
16 Sept	41						
17 Sept	42						
18 Sept	43						
19 Sept	44	75.2	12.8	4.89	0.015	<0.010	12.2
AVERAGE		77.1	11.5	4.9	0.008	0.000	11.8
STANDARD DEVIATION		1.57	0.96	0.60	0.01	0.00	2.28

Table E14

Activated Sludge Study

Reactor 3 Nutrient Data

DATE	DAY	NUTRIENTS ppm					
		REACTOR 8 DAY					
		TKN	TP	OPO4	NO-2N	NO3-N	NH3-N
7 Aug	1						
8 Aug	2						
9 Aug	3						
10 Aug	4	88.2	14.1	6.53	<0.010	<0.050	11.0
11 Aug	5						
12 Aug	6						
13 Aug	7						
14 Aug	8						
15 Aug	9						
16 Aug	10						
17 Aug	11	77.2	12.1	6.16	<0.010	<0.050	14.0
18 Aug	12						
19 Aug	13						
20 Aug	14						
21 Aug	15						
22 Aug	16						
23 Aug	17						
24 Aug	18	77.8	11.8	6.88	<0.010	<0.050	22.4
25 Aug	19						
26 Aug	20						
27 Aug	21						
28 Aug	22						
29 Aug	23						
30 Aug	24						
31 Aug	25	76.8	11.1	5.33	<0.010	<0.050	15.4
1 Sept	26						
2 Sept	27						
3 Sept	28						
4 Sept	29						
5 Sept	30						
6 Sept	31						
7 Sept	32						
8 Sept	33						
9 Sept	34						
10 Sept	35						
11 Sept	36	76.4	12.7	5.66	0.018	<0.010	14.9
12 Sept	37						
13 Sept	38						
14 Sept	39	91.2	13.8	5.58	0.019	0.01	18.2

(Continued)

E29

DATE	DAY	NUTRIENTS ppm					
		REACTOR 8 DAY					
		TKN	TP	OPO4	NO-2N	NO3-N	NH3-N
15 Sept	40						
16 Sept	41						
17 Sept	42						
18 Sept	43						
19 Sept	44	273	34.5	5.98	0.025	<0.010	13.2
AVERAGE		69.7	10.8	6.0	0.009	0.001	15.6
STANDARD DEVIATION		28.98	4.52	0.51	0.01	0.00	3.44

Table E15

Activated Sludge Study

Reactor 4 Nutrient Data

DATE	DAY	NUTRIENTS ppm					
		REACTOR 16 DAY					
		TKN	TP	OPO4	NO-2N	NO3-N	NH3-N
7 Aug	1						
8 Aug	2						
9 Aug	3						
10 Aug	4	81.6	13.0	5.89	<0.010	<0.050	8.22
11 Aug	5						
12 Aug	6						
13 Aug	7						
14 Aug	8						
15 Aug	9						
16 Aug	10						
17 Aug	11	70.2	9.8	5.52	<0.010	<0.050	14.30
18 Aug	12						
19 Aug	13						
20 Aug	14						
21 Aug	15						
22 Aug	16						
23 Aug	17						
24 Aug	18	79.6	10.6	5.97	<0.010	<0.050	22.70
25 Aug	19						
26 Aug	20						
27 Aug	21						
28 Aug	22						
29 Aug	23						
30 Aug	24						
31 Aug	25	86.0	16.3	10.60	<0.010	<0.050	18.20
1 Sept	26						
2 Sept	27						
3 Sept	28						
4 Sept	29						
5 Sept	30						
6 Sept	31						
7 Sept	32						
8 Sept	33						
9 Sept	34						
10 Sept	35						
11 Sept	36	67.6	12.1	5.99	0.013	0.013	18.80
12 Sept	37						
13 Sept	38						
14 Sept	39	75.6	13.5	6.51	0.027	<0.010	11.50

(Continued)

E31

DATE	DAY	NUTRIENTS ppm					
		REACTOR 16 DAY					
		TKN	TP	OPO4	NO-2N	NO3-N	NH3-N
15 Sept	40						
16 Sept	41						
17 Sept	42						
18 Sept	43						
19 Sept	44	72.8	10.6	5.04	0.016	<0.010	14.50
AVERAGE		76.2	12.3	6.5	0.008	0.002	15.5
STANDARD DEVIATION		6.08	2.07	1.72	0.01	0.00	4.50

Table E16

Activated Sludge Study

pH Data

DATE	DAY	2 DAY	4 DAY	8 DAY	16 DAY	CONTROL	INFLUENT
7 Aug	1	8.40	8.57	8.50	8.40	8.20	6.80
8 Aug	2	8.43	8.55	8.41	8.50	8.16	6.75
9 Aug	3	8.41	8.60	8.41	8.48	8.57	6.35
10 Aug	4	8.48	8.53	8.38	8.41	8.57	6.65
11 Aug	5	8.65	8.66	8.48	8.68	8.63	6.84
12 Aug	6						
13 Aug	7						
14 Aug	8	8.55	8.59	8.48	8.50	8.62	6.77
15 Aug	9	8.56	8.54	8.40	8.42	8.60	6.80
16 Aug	10	8.65	8.67	8.50	8.52	8.58	6.73
17 Aug	11	8.41	8.48	8.38	8.46	8.41	6.76
18 Aug	12	8.49	8.52	8.49	8.44	8.30	6.82
19 Aug	13						
20 Aug	14						
21 Aug	15	8.56	8.56	8.57	8.60	8.21	6.78
22 Aug	16	8.56	8.57	8.52	8.67	8.34	6.75
23 Aug	17	8.57	8.56	8.53	8.65	8.29	6.79
24 Aug	18	8.53	8.51	8.49	8.59	8.48	6.92
25 Aug	19	8.54	8.56	8.51	8.63	8.52	6.69
26 Aug	20						
27 Aug	21						
28 Aug	22	8.41	8.52	8.60	8.71	8.59	6.83
29 Aug	23	8.49	8.47	8.57	8.55	8.43	6.93
30 Aug	24	8.44	8.42	8.56	8.64	8.36	6.85
31 Aug	25	8.46	8.44	8.49	8.56	8.37	6.83
1 Sept	26	8.57	8.64	8.52	8.49	8.22	6.87
2 Sept	27						
3 Sept	28						
4 Sept	29						
5 Sept	30						
6 Sept	31	8.58	8.61	8.41	8.53		7.22
7 Sept	32	8.57	8.64	8.44	8.54		6.82
8 Sept	33	8.52	8.54	8.45	8.49		6.83
9 Sept	34						
10 Sept	35						
11 Sept	36	8.51	8.83	8.56	8.45	8.76	7.07
12 Sept	37	8.48	8.48	8.53	8.41	8.38	6.87
13 Sept	38	8.72	8.48	8.58	8.44	8.49	6.88
14 Sept	39	8.75	8.48	8.55	8.51		6.96

(Continued)

E33

DATE	DAY	pH					
		2 DAY	4 DAY	8 DAY	16 DAY	CONTROL	INFLUENT
15 Sept	40	8.45	8.45	8.43	8.48		6.95
16 Sept	41						
17 Sept	42						
18 Sept	43	8.80	8.46	8.46	8.58	8.53	6.90
19 Sept	44	8.48	8.49	8.46	8.58		6.94
AVERAGE		8.53	8.55	8.49	8.53	8.44	6.83
STANDARD DEVIATION		0.10	0.08	0.06	0.09	0.16	0.14

APPENDIX F: UNREDUCED DATA FOR PAC/ACTIVATED SLUDGE STUDY

Table Fl

Powder Activated Carbon Phase Temperature Data

Powder Activated Carbon/Activated Sludge Study

DATE		DAY	TEMPERATURE Celsius					
			REACTOR					
			2 grams	4 grams	10 grams	16 grams	CONTROL
Nov	9	1	18	18	18	18	18
Nov	10	2	21	21	21	21	21
Nov	11	3	19	19	19	19	19
Nov	12	4	19	19	18	19	19
Nov	13	5	20	20	20	20	20
Nov	14	6	21	21	21	21	21
Nov	15	7	20	21	20	21	21
Nov	16	8	15	16	16	15	16
Nov	17	9	20	20	20	20	20
Nov	18	10	22	21	22	22	21
Nov	19	11	18	18	18	18	18
Nov	20	12	18	18	18	18	18
Nov	21	13	19	19	19	19	19
Nov	22	14	20	20	21	21	20
Nov	23	15	19	19	19	19	19
Nov	24	16	19	19	19	19	19
Nov	25	17	19	19	20	20	19
Nov	26	18	20	20	20	20	19
Nov	27	19	21	21	20	20	21
Nov	28	20	20	20	20	20	20
Nov	29	21	16	16	17	17	16
Nov	30	22	16	16	16	16	16
Dec	1	23	20	21	21	20	21
Dec	2	24	20	20	21	21	20
Dec	3	25	20	20	20	20	21
Dec	4	26	19	20	20	19	19
Dec	5	27	21	21	21	21	21
Dec	6	28	20	20	20	20	20
Dec	7	29	20	21	21	20	20
Dec	8	30	20	20	20	20	20
Dec	9	31	19	19	19	19	19
Dec	10	32	19	20	20	19	19
Dec	11	33	20	20	20	20	20
Dec	12	34	21	21	21	21	21
Dec	13	35	20	20	20	20	20
Dec	14	36	21	21	21	21	21
Dec	15	37	21	21	21	21	21
Dec	16	38	20	20	21	21	21

(Continued)

F3

Table F1 (Concluded)

| | DATE | | DAY | | TEMPERATURE | | | |
| | | | | | Celsius | | | |

REACTOR

DATE		DAY		2 grams	4 grams	10 grams	16 grams	CONTROL
Dec 17		39		19	19	20	20	20
Dec 18		40		20	20	20	20	20
Dec 19		41		20	20	20	20	20
Dec 20		42		20	20	20	20	20
Dec 21		43		19	20	19	20	20
AVERAGE				20	20	20	20	20
STANDARD DEVIATION				1.37	1.31	1.32	1.36	1.33

Table F2

Powder Activated Carbon Phase pH Data

Ninth Avenue Bioreactors

Powder Activated Carbon/Activated Sludge Study

DATE	DAY	pH					
		REACTOR					
		2 grams	4 grams	10 grams	16 grams	CONTROL	INFLUENT
Nov 9	1	8.48	8.48	8.53	8.50	8.43	6.75
Nov 10	2	8.39	8.29	8.27	8.25	8.58	6.79
Nov 11	3						
Nov 12	4						
Nov 13	5	8.29	8.18	8.27	8.17	8.65	6.63
Nov 14	6	8.37	8.19	8.25	8.16	8.44	6.63
Nov 15	7	8.24	8.14	8.16	8.14	8.43	6.75
Nov 16	8	8.43	8.24	8.22	8.33	8.65	6.90
Nov 17	9	8.38	8.19	8.20	8.37	8.58	6.88
Nov 18	10						
Nov 19	11						
Nov 20	12	8.34	8.27	8.05	8.20	8.27	7.02
Nov 21	13	8.47	8.23	8.23	8.32	8.65	6.87
Nov 22	14	8.26	7.80	7.88	8.12	8.33	6.82
Nov 23	15						
Nov 24	16						
Nov 25	17						
Nov 26	18						
Nov 27	19	8.37	8.57	8.21	8.52	8.68	7.19
Nov 28	20	8.29	8.54	8.18	8.49	8.65	6.88
Nov 29	21	8.45	8.51	8.24	8.41	8.73	7.20
Nov 30	22	8.38	8.53	8.26	8.39	8.68	6.79
Dec 1	23	8.50	8.46	8.11	8.37	8.56	7.03
Dec 2	24						
Dec 3	25						
Dec 4	26	8.51	7.47	8.37	8.43	8.53	7.0
Dec 5	27	8.52	8.51	8.32	8.48	8.56	7.02
Dec 6	28	8.65	7.70	8.32	8.75	8.66	6.97
Dec 7	29	8.67	7.67	8.29	8.77	8.75	7.02
Dec 8	30	8.58	8.51	8.61	8.48	8.56	7.20
Dec 9	31						
Dec 10	32						
Dec 11	33						
Dec 12	34	8.44	8.44	8.00	7.93	8.44	7.0
Dec 13	35	8.47	8.38	7.98	7.97	8.39	6.98
Dec 14	36	8.42	8.40	8.33	8.25	8.43	6.91

(Continued)

DATE	DAY	pH					
		REACTOR					
		2 grams	4 grams	10 grams	16 grams	CONTROL	INFLUENT
Dec 15	37	8.38	8.43	8.31	8.27	8.48	7.02
Dec 16	38						
Dec 17	39						
Dec 18	40						
Dec 19	41	8.47	8.37	8.44	8.34	8.66	7.02
Dec 20	42	8.45	8.31	8.49	8.30	8.55	7.05
Dec 21	43	8.64	8.40	8.23	8.14	8.38	7.03
AVERAGE		8.44	8.27	8.25	8.33	8.54	6.94
STANDARD DEVIATION		0.11	0.28	0.16	0.19	0.12	0.15

Table F3

Powder Activated Carbon Phase Dissolved Oxygen Data

Ninth Avenue Bioreactors

Powder Activated Carbon/Activated Sludge Study

DATE	DAY	DISSOLVED OXYGEN mg/l				
		REACTOR				
		2 grams	4 grams	10 grams	16 grams	CONTROL
Nov 9	1	9.2	7.2	8.2	8.8	7.9
Nov 10	2	7.5	6.5	7.3	7.5	5.8
Nov 11	3					
Nov 12	4					
Nov 13	5	7.6	7.5	6.4	6.2	6.8
Nov 14	6	7.5	6.3	6.4	5.9	6.1
Nov 15	7	7.1	5.5	6.3	6.4	5.5
Nov 16	8	7.9	6.8	8.2	7.9	8.3
Nov 17	9	7.8	6.8	6.1	6.6	6.8
Nov 18	10					
Nov 19	11					
Nov 20	12	8.3	8.7	8.6	9.4	8.7
Nov 21	13	7.0	6.1	6.9	7.5	7.7
Nov 22	14	7.0	7.2	7.0	8.4	7.7
Nov 23	15					
Nov 24	16					
Nov 25	17	6.8	7.2	7.2	6.7	5.3
Nov 26	18	6.7	7.0	7.3	7.1	6.5
Nov 27	19	6.5	5.4	6.5	6.4	7.0
Nov 28	20	6.6	7.7	6.3	7.6	7.2
Nov 29	21	7.2	7.5	7.1	8.0	8.1
Nov 30	22	8.6	8.6	8.7	8.3	5.8
Dec 1	23	7.7	6.7	6.9	7.9	6.2
Dec 2	24					
Dec 3	25					
Dec 4	26	8.2	8.3	6.9	7.8	5.7
Dec 5	27	6.0	5.2	6.3	7.3	5.7
Dec 6	28	7.4	5.8	7.6	7.5	5.7
Dec 7	29	6.2	5.3	6.6	8.1	5.4
Dec 8	30	6.4	5.0	7.2	7.8	5.0
Dec 9	31					
Dec 10	32					
Dec 11	33					
Dec 12	34	6.7	5.5	7.3	6.5	4.5

(Continued)

DATE	DAY	DISSOLVED OXYGEN mg/1				
		REACTOR				
		2 grams	4 grams	10 grams	16 grams	CONTROL
Dec 13	35	6.9	5.4	6.4	5.5	4.7
Dec 14	36	6.5	5.3	7.1	5.8	4.5
Dec 15	37	7.0	5.7	6.0	6.5	4.5
Dec 16	38					
Dec 17	39					
Dec 18	40					
Dec 19	41	6.8	5.9	7.4	7.3	7.8
Dec 20	42	7.8	6.2	7.9	6.5	5.3
Dec 21	43	8.5	6.5	7.8	7.4	7.2
AVERAGE		7.3	6.5	7.1	7.3	6.3
STANDARD DEVIATION		0.8	1.0	0.7	0.9	1.2

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Table F4

Powder Activated Carbon Phase Salinity Data

Ninth Avenue Bioreactors

Powder Activated Carbon/Activated Sludge Study

DATE	DAY	SALINITY parts/thousand					
		REACTOR					
		2 grams	4 grams	10 grams	16 grams	CONTROL	INFLUENT
Nov 9	1	1.9	1.0	1.5	1.7	1.5	3.0
Nov 10	2	1.5	1.2	1.9	1.3	1.8	2.5
Nov 11	3						
Nov 12	4						
Nov 13	5	1.5	1.3	1.6	1.5	1.8	2.6
Nov 14	6	1.5	1.7	1.3	1.5	2.0	3.0
Nov 15	7	1.6	1.8	1.9	1.9	2.0	3.0
Nov 16	8	1.8	1.8	1.9	1.3	1.8	2.9
Nov 17	9	1.8	2.0	1.8	1.5	1.8	3.0
Nov 18	10						
Nov 19	11						
Nov 20	12	1.8	1.8	1.8	1.7	1.5	3.0
Nov 21	13	1.4	1.5	1.5	1.6	1.8	2.5
Nov 22	14	1.5	1.3	1.8	1.6	1.9	2.2
Nov 23	15						
Nov 24	16						
Nov 25	17						
Nov 26	18						
Nov 27	19	1.8	1.5	1.9	1.9	1.8	2.5
Nov 28	20	1.9	1.8	1.9	1.5	1.8	2.3
Nov 29	21	1.8	1.9	1.8	1.8	1.9	2.5
Nov 30	22	1.9	1.9	1.8	1.8	2.0	2.5
Dec 1	23	1.9	1.9	1.8	1.8	2.0	2.5
Dec 2	24						
Dec 3	25						
Dec 4	26	1.9	1.8	1.9	1.6	1.9	2.5
Dec 5	27	1.9	1.8	1.8	1.3	1.8	2.8
Dec 6	28	1.8	1.9	1.9	1.5	1.8	2.5
Dec 7	29	1.8	1.9	1.9	1.6	1.9	2.8
Dec 8	30	1.8	1.8	1.5	1.5	1.9	2.9
Dec 9	31						
Dec 10	32						
Dec 11	33						
Dec 12	34	1.9	1.9	1.9	1.9	2.0	3.0
Dec 13	35	1.8	1.9	1.8	1.9	1.9	2.9
Dec 14	36	1.8	1.9	1.9	1.8	2.0	2.8

(Continued)

DATE	DAY	SALINITY parts/thousand					
		REACTOR				CONTROL	INFLUENT
		2 grams	4 grams	10 grams	16 grams	CONTROL	INFLUENT
Dec 15	37	1.9	1.9	1.9	1.9	2.0	2.9
Dec 16	38						
Dec 17	39						
Dec 18	40						
Dec 19	41	1.8	1.8	1.6	1.9	2.0	2.9
Dec 20	42	1.8	1.8	1.7	1.8	2.0	2.9
Dec 21	43	1.8	1.8	1.8	1.6	1.9	2.8
AVERAGE		1.8	1.7	1.8	1.7	1.9	2.7
STANDARD DEVIATION		0.1	0.2	0.2	0.2	0.1	0.2

Table F5

Conductivity Data

Powder Activated Carbon/Activated Sludge Study

DATE	DAY	CONDUCTIVITY micromhos/cm					
		REACTOR					
		2 grams	4 grams	10 grams	16 grams	CONTROL	INFLUENT
Nov 9	1	2200	2700	2800	2800	2500	4400
Nov 10	2	2800	2750	2900	2600	2800	4500
Nov 11	3						
Nov 12	4						
Nov 13	5	2500	2300	2650	2600	2800	4050
Nov 14	6	2800	2900	2600	2650	3050	4600
Nov 15	7	2700	2850	2800	2750	3000	4500
Nov 16	8	2650	2700	2650	2500	2800	4200
Nov 17	9	2900	2900	2900	2850	3000	4500
Nov 18	10						
Nov 19	11						
Nov 20	12	2700	2700	2700	2600	2400	4000
Nov 21	13	2700	2800	2750	2700	3000	4050
Nov 22	14	2600	2300	2840	2650	2900	2670
Nov 23	15						
Nov 24	16						
Nov 25	17						
Nov 26	18						
Nov 27	19	2850	2750	2900	2900	3000	3400
Nov 28	20	2900	2900	2750	2700	2900	3200
Nov 29	21	2800	2850	2700	2600	2900	3700
Nov 30	22	2650	2700	2700	2600	2750	3300
Dec 1	23	2700	2750	2750	2600	2700	3400
Dec 2	24						
Dec 3	25						
Dec 4	26	2800	2900	2750	2700	3000	3200
Dec 5	27	2600	2900	2800	2500	3000	4400
Dec 6	28	2900	2800	2800	2700	2900	3100
Dec 7	29	2800	3000	2850	2700	3000	4400
Dec 8	30	2800	2900	2700	2750	3000	4500
Dec 9	31						
Dec 10	32						
Dec 11	33						
Dec 12	34	2900	3050	2950	2900	3050	4500
Dec 13	35	2950	3050	2800	3000	3050	4600
Dec 14	36	2950	2900	2900	2850	3000	4000
Dec 15	37	3150	3200	3050	3100	3250	4850

(Continued)

F11

DATE	DAY	CONDUCTIVITY micromhos/cm					
		REACTOR					
		2 grams	4 grams	10 grams	16 grams	CONTROL	INFLUENT
Dec 16	38						
Dec 17	39						
Dec 18	40						
Dec 19	41	2950	3000	2700	2900	3050	4500
Dec 20	42	2900	3100	2900	3050	3200	4500
Dec 21	43	2800	2950	2800	2800	3200	4500
AVERAGE		2776	2837	2792	2743	2933	4056
STANDARD DEVIATION		173.4	194.8	100.4	153.4	184.7	568.2

Table F6
Powder Activated Carbon/Activated Sludge Study
Suspended Solids Data

DATE	DAY	SUSPENDED SOLIDS mg/l				
		REACTOR				
		2 grams	4 grams	10 grams	16 grams	CONTROL
Nov 9	1	7627	11167	11633	19687	7420
Nov 10	2					
Nov 11	3					
Nov 12	4					
Nov 13	5					
Nov 14	6	11773	13693	19707	31580	9040
Nov 15	7					
Nov 16	8	9247	12227	13378	17322	6740
Nov 17	9					
Nov 18	10					
Nov 19	11					
Nov 20	12					
Nov 21	13	13511	14344	19289	23867	4111
Nov 22	14					
Nov 23	15					
Nov 24	16					
Nov 25	17					
Nov 26	18					
Nov 27	19					
Nov 28	20	12722	4933	21733	28044	3777
Nov 29	21					
Nov 30	22	9244	9722	12422	27444	2333
Dec 1	23					
Dec 2	24					
Dec 3	25					
Dec 4	26					
Dec 5	27	8013	9880	22460	29553	4513
Dec 6	28					
Dec 7	29	14360	8233	27313	21533	3307
Dec 8	30					
Dec 9	31					
Dec 10	32					
Dec 11	33					
Dec 12	34	13280	10013	26900	27560	4647
Dec 13	35					
Dec 14	36					
Dec 15	37					

(Continued)

F13

Table F6 (Concluded)

DATE	DAY	SUSPENDED SOLIDS mg/1				
		REACTOR				
		2 grams	4 grams	10 grams	16 grams	CONTROL
Dec 16	38					
Dec 17	39					
Dec 18	40					
Dec 1	41	14600	12413	29153	33740	2493
Dec 20	42					
Dec 21	43					
AVERAGE		11438	10663	20399	26033	4838
STANDARD DEVIATION		2409	2507	5754	4787	1997

Table F7

Powder Activated Carbon/Activated Sludge Study

Volatile Suspended Solids Data

DATE	DAY	VOLATILE SUSPENDED SOLIDS mg/l				
		REACTOR				
		2 grams	4 grams	10 grams	16 grams	CONTROL
Nov 9	1	2780	4060	5373	9327	2267
Nov 10	2					
Nov 11	3					
Nov 12	4					
Nov 13	5					
Nov 14	6	4207	6847	9713	16907	2560
Nov 15	7					
Nov 16	8	370	1773	1360	3878	
Nov 17	9					
Nov 18	10					
Nov 19	11					
Nov 20	12					
Nov 21	13	6832	4967	10256	14211	1644
Nov 22	14					
Nov 23	15					
Nov 24	16					
Nov 25	17					
Nov 26	18					
Nov 27	19					
Nov 28	20	5011	3222	11478	16277	2067
Nov 29	21					
Nov 30	22	4844	5733	7844	16755	1600
Dec 1	23					
Dec 2	24					
Dec 3	25					
Dec 4	26					
Dec 5	27	3600	3853	12173	16613	1620
Dec 6	28					
Dec 7	29	5427	4200	14033	13053	1286
Dec 8	30					
Dec 9	31					
Dec 10	32					
Dec 11	33					
Dec 12	34	5013	4827	14040	16047	1807
Dec 13	35					
Dec 14	36					
Dec 15	37					

(Continued)

Table F7 (Concluded)

DATE	DAY	VOLATILE SUSPENDED SOLIDS mg/l				
		REACTOR				
		2 grams	4 grams	10 grams	16 grams	CONTROL
Dec 16	38					
Dec 17	39					
Dec 18	40					
Dec 19	41	5853	5653	15347	19213	1320
Dec 20	42					
Dec 21	43					
AVERAGE		4394	4514	10162	14228	1797
STANDARD DEVIATION		1721.6	1423.0	3988.8	4182.5	388.8

Table F8

Powder Activated Carbon/Activated Sludge Study

Sludge Volume Index Data

DATE	DAY	SLUDGE VOLUME INDEX mg/l			
		REACTOR			
		2 grams	4 grams	10 grams	16 grams
Nov 9	1				
Nov 10	2				
Nov 11	3				
Nov 12	4				
Nov 13	5				
Nov 14	6				
Nov 15	7				
Nov 16	8				
Nov 17	9				
Nov 18	10				
Nov 19	11				
Nov 20	12				
Nov 21	13	22	39	24	19
Nov 22	14				
Nov 23	15				
Nov 24	16				
Nov 25	17				
Nov 26	18				
Nov 27	19				
Nov 28	20	21	25	20	25
Nov 29	21				
Nov 30	22	20	16	18	39
Dec 1	23				
Dec 2	24				
Dec 3	25				
Dec 4	26				
Dec 5	27	18	18	20	28
Dec 6	28				
Dec 7	29				
Dec 8	30	14	9	13	19
Dec 9	31				
Dec 10	32				
Dec 11	33				
Dec 12	34				
Dec 13	35				
Dec 14	36	8	8	22	27
Dec 15	37				

(Continued)

F17

DATE	DAY	SLUDGE VOLUME INDEX mg/l			
		REACTOR			
		2 grams	4 grams	10 grams	16 grams
Dec 16	38				
Dec 17	39				
Dec 18	40				
Dec 19	41				
Dec 20	42				
Dec 21	43				
AVERAGE		17	19	20	26
STANDARD DEVIATION		4.5	9.8	3.2	6.2

Table F9
Powder Activated Carbon/Activated Sludge Study
Total Organic Carbon Data

DATE	DAY	TOTAL ORGANIC CARBON ppm					
		REACTOR					
		2 grams	4 grams	10 grams	16 grams	CONTROL	INFLUENT
Nov 9	1	400.5	351.0	405.0	331.5	370.5	
Nov 10	2						
Nov 11	3						
Nov 12	4						
Nov 13	5						
Nov 14	6	354.0	237.0	189.0	136.5	316.5	
Nov 15	7						
Nov 16	8	364.5	301.5	154.5	145.5	327.0	
Nov 17	9						
Nov 18	10						
Nov 19	11						
Nov 20	12						
Nov 21	13	381.0	279.0	195.0	109.5	312.0	
Nov 22	14						
Nov 23	15						
Nov 24	16						
Nov 25	17	354.0	337.5	192.0	100.5	243.0	
Nov 26	18						
Nov 27	19						
Nov 28	20	249.0	259.0	192.0	252.0	282.0	
Nov 29	21						
Nov 30	22	255.0	300.0	213.0	115.5	268.5	790.5
Dec 1	23						
Dec 2	24						
Dec 3	25						
Dec 4	26						
Dec 5	27	262.5	262.5	117.0	87.0	361.5	
Dec 6	28						
Dec 7	29						
Dec 8	30						
Dec 9	31	303.0	352.5	103.5	90.0	258.0	
Dec 10	32						
Dec 11	33						
Dec 12	34	222.0	244.5	166.5	219.0	249.0	820.5
Dec 13	35						
Dec 14	36						
Dec 15	37						

(Continued)

F19

DATE	DAY	TOTAL ORGANIC CARBON ppm					

		REACTOR					
		2 grams	4 grams	10 grams	16 grams	CONTROL	INFLUENT
Dec 16	38						
Dec 17	39	216.0	261.0	93.0	84.0	327.0	720.0
Dec 18	40						
Dec 19	41	210.0	195.0	90.0	69.0	237.0	769.0
Dec 20	42						
Dec 21	43						
AVERAGE		297.6	281.7	175.9	145.0	296.0	775.0
STANDARD DEVIATION		67.0	46.4	80.8	77.3	44.1	36.6
PERCENT REDUCTION		61.6	63.7	77.3	81.3	61.8	

Table F10

Powder Activated Carbon/Activated Sludge Study

Chemical Oxygen Demand Data

DATE	DAY	CHEMICAL OXYGEN DEMAND ppm					
		REACTOR					
		2 grams	4 grams	10 grams	16 grams	CONTROL	INFLUENT
Nov 9	1						
Nov 10	2						
Nov 11	3						
Nov 12	4						
Nov 13	5						
Nov 14	6	1230	1010	700	641	1120	4350
Nov 15	7						
Nov 16	8	1230	1000	631	544	1070	
Nov 17	9						
Nov 18	10						
Nov 19	11						
Nov 20	12						
Nov 21	13	1130	1075	787	390	1170	
Nov 22	14						
Nov 23	15						
Nov 24	16						
Nov 25	17	1100	1230	798	483	1170	
Nov 26	18						
Nov 27	19						
Nov 23	20	961	1000	744	346	399	
Nov 29	21						
Nov 30	22	918	1130	811	390	1250	3430
Dec 1	23						
Dec 2	24						
Dec 3	25						
Dec 4	26						
Dec 5	27	929	1120	647	404	1210	
Dec 6	28						
Dec 7	29	1040	1250	608	386	1150	
Dec 8	30						
Dec 9	31						
Dec 10	32						
Dec 11	33						
Dec 12	34	928	778	744	938	1210	3480
Dec 13	35						
Dec 14	36						
Dec 15	37						

(Continued)

Table F10 (Concluded)

DATE	DAY	CHEMICAL OXYGEN DEMAND ppm					
		REACTOR					
		2 grams	4 grams	10 grams	16 grams	CONTROL	INFLUENT
Dec 16	38						
Dec 17	39	947	1140	506	440	1220	
Dec 18	40						
Dec 19	41	909	958	428	423	1200	3520
Dec 20	42						
Dec 21	43						
AVERAGE		1029	1063	673	490	1106	3695
STANDARD DEVIATION		118.5	127.8	118.0	163.0	228.8	379.5
PERCENT REDUCTION		72.1	71.2	81.8	86.8	70.1	

Table F11

Powder Activated Carbon/Activated Sludge Study

Biochemical Oxygen Demand Data

DATE	DAY	CHEMICAL OXYGEN DEMAND mg/l					
		REACTOR					
		2 grams	4 grams	10 grams	16 grams	CONTROL	INFLUENT
Nov 9	1						
Nov 10	2						
Nov 11	3						
Nov 12	4						
Nov 13	5						
Nov 14	6						
Nov 15	7	117.5	109.90	26.50	56.90	111.20	1341.90
Nov 16	8						
Nov 17	9	82.8	103.20	34.50	75.50	100.50	1441.90
Nov 18	10						
Nov 19	11						
Nov 20	12						
Nov 21	13						
Nov 22	14	146.3	119.50	110.30	18.40	113.60	1394.20
Nov 23	15						
Nov 24	16						
Nov 25	17						
Nov 26	18						
Nov 27	19						
Nov 28	20						
Nov 29	21	40.06	159.70	31.10	24.90	98.40	1521.00
Nov 30	22						
Dec 1	23	44.5	126.80	82.20	20.80	148.80	1768.00
Dec 2	24						
Dec 3	25						
Dec 4	26						
Dec 5	27						
Dec 6	28	66.5	128.20	31.30	18.70	118.20	1597.20
Dec 7	29						
Dec 8	30	82.8	151.90	35.40	34.90	133.30	1744.00
Dec 9	31						
Dec 10	32						
Dec 11	33						
Dec 12	34						
Dec 13	35	44.4	132.60	89.20	59.60	136.10	1746.00
Dec 14	36						
Dec 15	37	97.3	117.20	38.70	22.60	140.70	1946.80

(Continued)

DATE	DAY	CHEMICAL OXYGEN DEMAND mg/l					
		REACTOR					
		2 grams	4 grams	10 grams	16 grams	CONTROL	INFLUENT
Dec 16	38						
Dec 17	39						
Dec 18	40						
Dec 19	41						
Dec 20	42						
Dec 21	43						
AVERAGE		80.2	127.7	53.2	36.9	122.3	1611.2
SD		34.03	17.41	29.73	20.25	17.04	191.38
% REDUCTION		95.02	92.08	96.70	97.71	92.41	

Table F12
Powder Activated Carbon/Activated Sludge Study
Reactor 1 Nutrient Data

DATE	DAY	NUTRIENTS					
		REACTOR 2 GRAMS CARBON					
		TKN	TP	OPO4	NO2-N	NO3-N	NH3-N
Nov 9	1						
Nov 10	2						
Nov 11	3						
Nov 12	4						
Nov 13	5						
Nov 14	6						
Nov 15	7						
Nov 16	8	72.40	10.60	6.58	0.023	<0.010	18.00
Nov 17	9						
Nov 18	10						
Nov 19	11						
Nov 20	12						
Nov 21	13						
Nov 22	14						
Nov 23	15						
Nov 24	16						
Nov 25	17	59.60	9.00	6.82	0.016	0.021	25.10
Nov 26	18						
Nov 27	19						
Nov 28	20						
Nov 29	21						
Nov 30	22	29.20	4.68	2.53	0.010	<0.010	3.46
Dec 1	23						
Dec 2	24						
Dec 3	25						
Dec 4	26						
Dec 5	27						
Dec 6	28						
Dec 7	29	49.80	5.36	3.34	0.020	<0.010	18.60
Dec 8	30						
Dec 9	31						
Dec 10	32						
Dec 11	33						
Dec 12	34						
Dec 13	35						
Dec 14	36						
Dec 15	37						

(Continued)

Table F12 (Concluded)

DATE	DAY	NUTRIENTS					
		REACTOR 2 GRAMS CARBON					
		TKN	TP	OPO4	NO2-N	NO3-N	NH3-N
Dec 16	38						
Dec 17	39	53.80	8.02	4.52	0.036	<0.010	7.62
Dec 18	40						
Dec 19	41						
Dec 20	42						
Dec 21	43						
AVERAGE		52.960	7.532	4.758	0.021	0.004	14.556
SD		14.123	2.221	1.709	0.009	0.008	7.882

Table F13
Powder Activated Carbon/Activated Sludge Study
Reactor 2 Nutrient Data

DATE	DAY	NUTRIENTS					
		REACTOR 4 GRAMS CARBON					
		TKN	TP	OPO4	NO2-N	NO3-N	NH3-N
Nov 9	1						
Nov 10	2						
Nov 11	3						
Nov 12	4						
Nov 13	5						
Nov 14	6						
Nov 15	7						
Nov 16	8	58.00	7.48	3.18	0.012	<0.010	6.58
Nov 17	9						
Nov 18	10						
Nov 19	11						
Nov 20	12						
Nov 21	13						
Nov 22	14						
Nov 23	15						
Nov 24	16						
Nov 25	17	58.00	8.60	5.15	<0.010	<0.010	6.91
Nov 26	18						
Nov 27	19						
Nov 28	20						
Nov 29	21						
Nov 30	22	62.20	10.50	7.40	0.024	<0.010	17.70
Dec 1	23						
Dec 2	24						
Dec 3	25						
Dec 4	26						
Dec 5	27						
Dec 6	28						
Dec 7	29	52.20	5.38	3.84	0.018	<0.010	29.40
Dec 8	30						
Dec 9	31						
Dec 10	32						
Dec 11	33						
Dec 12	34						
Dec 13	35						
Dec 14	36						
Dec 15	37						

(Continued)

Table F13 (Concluded)

DATE	DAY	NUTRIENTS					
		REACTOR 4 GRAMS CARBON					
		TKN	TP	OPO4	NO2-N	NO3-N	NH3-N
Dec 16	38						
Dec 17	39	50.20	7.08	4.66	0.024	<0.010	19.80
Dec 18	40						
Dec 19	41						
Dec 20	42						
Dec 21	43						
AVERAGE		56.120	7.808	4.846	0.016	0.000	16.078
SD		4.346	1.697	1.445	0.009	0.000	8.582

Table F14
Powder Activated Carbon/Activated Sludge Study
Reactor 3 Nutrient Data

DATE	DAY	NUTRIENTS					
		REACTOR 10 GRAMS CARBON					
		TKN	TP	OPO4	NO2-N	NO3-N	NH3-N
Nov 9	1						
Nov 10	2						
Nov 11	3						
Nov 12	4						
Nov 13	5						
Nov 14	6						
Nov 15	7						
Nov 16	8	40.8	5.58	2.31	0.012	0.024	5.85
Nov 17	9						
Nov 18	10						
Nov 19	11						
Nov 20	12						
Nov 21	13						
Nov 22	14						
Nov 23	15						
Nov 24	16						
Nov 25	17	47.2	5.68	2.17	0.011	<0.010	3.23
Nov 26	18						
Nov 27	19						
Nov 28	20						
Nov 29	21						
Nov 30	22	49.6	6.98	2.48	0.041	<0.010	4.86
Dec 1	23						
Dec 2	24						
Dec 3	25						
Dec 4	26						
Dec 5	27						
Dec 6	28						
Dec 7	29	54.8	6.00	3.55	0.024	<.010	25.00
Dec 8	30						
Dec 9	31						
Dec 10	32						
Dec 11	33						
Dec 12	34						
Dec 13	35						
Dec 14	36						
Dec 15	37						

(Continued)

F29

DATE	DAY	NUTRIENTS					
		REACTOR 10 GRAMS CARBON					
		TKN	TP	OPO4	NO2-N	NO3-N	NH3-N
Dec 16	38						
Dec 17	39	43.4	5.40	2.94	0.024	<0.010	14.40
Dec 18	40						
Dec 19	41						
Dec 20	42						
Dec 21	43						
AVERAGE		47.160	5.928	2.690	0.022	0.005	10.668
SD		4.877	0.561	0.502	0.011	0.010	8.144

Table F15

Powder Activated Carbon/Activated Sludge Study

Reactor 4 Nutrient Data

DA	DAY	NUTRIENTS					
		REACTOR 16 GRAMS CARBON					
		TKN	TP	OPO4	NO2-N	NO3-N	NH3-N
Nov 9	1						
Nov 10	2						
Nov 11	3						
Nov 12	4						
Nov 13	5						
Nov 14	6						
Nov 15	7						
Nov 16	8	75.2	10.20	3.95	0.013	0.010	8.39
Nov 17	9						
Nov 18	10						
Nov 19	11						
Nov 20	12						
Nov 21	13						
Nov 22	14						
Nov 23	15						
Nov 24	16						
Nov 25	17	37.9	5.04	2.64	0.010	0.014	7.82
Nov 26	18						
Nov 27	19						
Nov 28	20						
Nov 29	21						
Nov 30	22	31.2	5.44	2.93	0.024	0.012	5.35
Dec 1	23						
Dec 2	24						
Dec 3	25						
Dec 4	26						
Dec 5	27						
Dec 6	28						
Dec 7	29	39.0	5.28	3.61	0.022	<0.010	17.20
Dec 8	30						
Dec 9	31						
Dec 10	32						
Dec 11	33						
Dec 12	34						
Dec 13	35						
Dec 14	36						
Dec 15	37						

(Continued)

DATE	DAY	NUTRIENTS					

		REACTOR 16 GRAMS CARBON					
		TKN	TP	OPO4	NO2-N	NO3-N	NH3-N
Dec 16	38						
Dec 17	39	30.6	4.58	2.82	0.022	<0.010	8.72
Dec 18	40						
Dec 19	41						
Dec 20	42						
Dec 21	43						
AVERAGE		42.780	6.108	3.190	0.018	0.007	9.496
SD		16.563	2.066	0.502	0.006	0.006	4.029

Table F16
Powder Activated Carbon/Activated Sludge Study
Reactor 5 Nutrient Data

DATE	DAY	NUTRIENTS					
		REACTOR 10 GRAMS CARBON					
		TKN	TP	OPO4	NO2-N	NO3-N	NH3-N
Nov 9	1						
Nov 10	2						
Nov 11	3						
Nov 12	4						
Nov 13	5						
Nov 14	6						
Nov 15	7						
Nov 16	8	63.2	9.36	4.84	0.034	0.014	16.00
Nov 17	9						
Nov 18	10						
Nov 19	11						
Nov 20	12						
Nov 21	13						
Nov 22	14						
Nov 23	15						
Nov 24	16						
Nov 25	17	64.8	9.88	6.23	0.016	0.010	26.10
Nov 26	18						
Nov 27	19						
Nov 28	20						
Nov 29	21						
Nov 30	22	68.0	9.72	5.08	0.038	<0.010	15.40
Dec 1	23						
Dec 2	24						
Dec 3	25						
Dec 4	26						
Dec 5	27						
Dec 6	28						
Dec 7	29	59.4	8.20	4.65	0.029	<0.010	18.10
Dec 8	30						
Dec 9	31						
Dec 10	32						
Dec 11	33						
Dec 12	34						
Dec 13	35						
Dec 14	36						
Dec 15	37						

(Continued)

DATE	DAY	NUTRIENTS					
		REACTOR 10 GRAMS CARBON					
		TKN	TP	OPO4	NO2-N	NO3-N	NH3-N
Dec 16	38						
Dec 17	39	65.2	10.90	5.59	0.028	<0.010	6.56
Dec 18	40						
Dec 19	41						
Dec 20	42						
Dec 21	43						
AVERAGE		64.120	9.612	5.278	0.029	0.005	16.432
SD		2.822	0.872	0.571	0.007	0.006	6.244

Table F17

Powder Activated Carbon/Activated Sludge Study

HNU Data

DATE	DAY	REACTOR				HNU READINGS ppm	
		2 grams	4 grams	10 grams	16 grams	CONTROL	INFLUENT
Nov 9	1						
Nov 10	2						
Nov 11	3						
Nov 12	4						
Nov 13	5	0.4	0.3	0.2	0.2	0.1	30.0
Nov 14	6						
Nov 15	7						
Nov 16	8	0.4	0.4	0.3	0.2	0.3	7.0
Nov 17	9						
Nov 18	10						
Nov 19	11						
Nov 20	12						
Nov 21	13	0.6	0.6	1.0	0.4	0.4	13.0
Nov 22	14						
Nov 23	15						
Nov 24	16						
Nov 25	17						
Nov 26	18						
Nov 27	19						
Nov 28	20	0.8	0.6	0.4	0.2	0.4	20.0
Nov 29	21						
Nov 30	22	0.8	0.6	1.0	0.4	0.4	10.0
Dec 1	23						
Dec 2	24						
Dec 3	25						
Dec 4	26						
Dec 5	27	0.2	0.4	0.4	0.4	0.4	14.0
Dec 6	28						
Dec 7	29						
Dec 8	30	0.6	0.6	0.8	0.6	0.6	4.0
Dec 9	31						
Dec 10	32						
Dec 11	33						
Dec 12	34	0.5	0.4	0.4	0.4	0.5	10.0
Dec 13	35	0.6	0.6	0.4	0.4	0.4	4.5
Dec 14	36						
Dec 15	37						
Dec 16	38						

(Continued)

F35

Table F17 (Concluded)

DATE	DAY	HNU READINGS ppm					
		REACTOR				CONTROL	INFLUENT
		2 grams	4 grams	10 grams	16 grams		
Dec 17	39						
Dec 18	40						
Dec 19	41	0.8	0.8	0.6	0.6	0.4	4.0
Dec 20	42						
Dec 21	43						
AVERAGE		0.6	0.5	0.6	0.4	0.4	11.7
STANDARD DEVIATION		0.2	0.1	0.3	0.1	0.1	7.4

APPENDIX G: DAILY OBSERVATIONS AND COMMENTS ON
             BIOREACTOR OPERATIONS

Acclimation Study,
Microscopic Examination

19 January 89 The aeration tank contains primarily free-swimming ciliates and a few stalked ciliates. Several rotifers and round worms are also present. The flocs are thick, dense, and a light brown color.

20 January 89 Free-swimming ciliates dominate in the aeration tank. Several stalked ciliates, rotifers, and round worms are present. Flocs are a little smaller and not quite as dense as before. The overall color of the bioreactor is darker than yesterday.

23 January 89 The flocs are becoming more dense, and they are settling more slowly. Some floc material is present in the clarifier, but the effluent is clear.

24 January 89 The flocs continue to settle slowly. Filamentous floc formers are beginning to predominate. There are more stalked ciliates now than before.

25 January 89 The density of flocs in the aeration tank is increasing. The effluent still remains very clear. The filamentous material in the flocs continues to increase. Many free-swimming ciliates and stalked cilicates are present.

26 January 89 The filamentous material continues to increase. The density of the flocs is increasing also. The number of free-swimming and stalked ciliates is increasing.

28 January 89 The flocs are beginning to become smaller but are still very dense. The effluent is starting to becoming cloudy.

30 January 89 The aeration tank has a lot of filamentous material in it. Rotifers are the dominate organism present in the aeration tank. Stalked and free-swimming ciliates, and a few worms, are present too.

31 January 89 The filamentous material still dominates. Rotifers are still the dominate organism. Stalked and free-swimming ciliates are present also.

1 February 89 Filamentous material is present in large amounts. There are more rotifers present than free-swimming and stalked ciliates; however, their numbers are increasing also. A few *Paramecium* and round worms are present also. The effluent is ,ecoming more cloudy.

3 February 89 Rotifers continue to be the dominant species present. There are stalked ciliates and a few free-swimming ciliates present. Filamentous material is still present in large amounts.

6 February 89 The electricity was off due to an ice storm. The bioreactors were without air for a few hours. A tank of compressed air was connected to bioreactors for an air supply.

8 February 89 A few stalked ciliates are still living, but no rotifers were present. The filamentous material is still present.

9 February 89 Several rotifers are present today. There are also a few stalked ciliates. Also present are very active, tiny spherical-shaped organisms that are too small to identify.

10 February 89 The diversity of living organisms is increasing. *Paramecium*, stalked and free-swimming ciliates, and many small very active unidentified organisms present. *Pleuronema* was present in very small numbers. The effluent is cloudy and an orange color.

13 February 89 The number of stalked ciliates is increasing. A few rotifers are present.

14 February 89 There are many stalked ciliates present. A few rotifers and *Paramecium* are present also. Filamentous material continues to be in sample. The flocs are a yellow/orange color.

17 February 89 There are a few free-swimming ciliates (*Pleuronema*) present. There are more stalked ciliates present than before, a few *Vorticella*. *Paramecium*, and a rew rotifers are in reactor.

18 February 89 Filamentous material is still present. Stalked and free-swimming ciliates and *Paramecium* are very numerous.

21 February 89 The number of free-swimming and stalked ciliates, *Pleuronema*, and *Paramecium*, is increasing. A few flat worms were present also.

28 February 89 *Pleuronema* is the dominant species present. Also present is *Paramecium*. Filamentous material is present in large amounts. Some flocs continue to be suspended in the water column after settling for 30 min.

2 March 89 Filamentous material present in large amounts. No stalked ciliates present. *Paramecium* and *Pleuronema* present although not in large numbers. A few rotifers are also present.

6 March 89 Free-swimming ciliates are present. A few flat worms, *Paramecium* and *Pleuronema*, are also present. No stalked ciliates are present.

8 March 89 Super Cee was added to bioreactor today.

9 March 89 The flocs are very small. Filamentous material still continues to dominate. Very few *Paramecium* seen. No other ciliates present. There are many very small organisms moving about that are very active, but too small to be identified.

10 March 89 The flocs continue to be very small. Filamentous material still dominates. A few *Paramecium* and *Pleuronema* are present. Very few stalked ciliates present. Since adding "Super Cee" there are many very small organisms moving about. No rotifers were observed.

13 March 89 There has been a major increase in number of organisms present. The predominant species is *Paramecium*. A few stalked ciliates are present. There are mostly free-swimming ciliates (*Stylonychia*, *Lionous*, *Pleuronema*)

G5

present. The flocs continue to be small with filamentous material still present.

14 March 89 *Paramecium* is still the dominant organism present. There are a few stalked ciliates present, *Stylonychia*; *Pleuronema* are present. The flocs are very small and a light brown color.

15 March 89 *Paramecium* is abundant in the aeration tank along with stalked ciliates, *Stylonychia*. *Paramecium* were also observed in the clarifier. Filamentous material is still abundant. The flocs are a light brown color and small.

17 March 89 The number of stalked ciliates is increasing. *Paramecium* and *Stylonychia* are present. Filamentous material still dominates. The floc size is increasing also.

21 March 89 There are mostly stalked ciliates in aeration tank. A few *Paramecium* and free-swimming ciliates are present.

24 March 89 The number of *Paramecium* has decreased greatly. There are a few stalked ciliates and free-swimming ciliates present.

27 March 89 *Paramecium* and *Stylonychia* present in aeration tank. A few stalked ciliates are present also. No rotifers were observed. Discontinued adding Super Cee today.

28 March 89 *Paramecium*, *Stylonychia*, and stalked ciliates present. Rotifers were not observed in the aeration tank. Filamentous material is still present in the bioreactor.

30 March 89 The clarifier has a brown scum on the surface of the water. Microscopic examination shows a proliferation of *Paramecium*. The aeration tank also has *Paramecium* and a few stalked ciliates. The filamentous material is still present.

31 March 89 The clarifier continues to have a brown scum containing many *Paramecium*. No other organisms are found in the clarifier. The aeration tank

contains a few *Paramecium* and rotifers. The flocs in the aeration tank are small.

3 April 89   The aeration tank has a few *Paramecium*. There is a proliferation of very small, too small to be identified, organisms in the aeration tank. They are swimming about very quickly and look like very tiny worms.

5 April 89   The aeration tank contains *Paramecium*, flat worms, and a few mites. Rotifers were observed again also.

10 April 89   There are many mites in the aeration tank today. A few *Paramecium* and stalked ciliates are also present. The large number of very tiny unidentified organisms continues to flourish. The filamentous material continues to be present in the bioreactor.

11 April 89   The unidentified very small organisms still present in large numbers. A few *Paramecium* and stalked ciliates are present also.

14 April 89   The flocs in the aeration tank are very dense. A few *Paramecium* round worms, and mites are present in aeration tank. The unidentified very small organisms still present in large numbers.

18 April 89   There are many hundreds of the unidentified organisms present. A few *Paramecium* and free-swimming ciliates are present.

20 April 89   The flocs in the aeration tank appear to be getting larger. Many of the unidentified very small organisms still present. A few *Paramecium* and mites are present also.

26 April 89   A new species of stalked ciliate is present, but unidentified. Other stalked ciliates were observed also. Rotifer were again present in the aeration tank. The unidentified very small organisms still present in large numbers.

28 April 89   The number of rotifers continues to increase. Mites, round worms, and stalked ciliates also found. Many of the unidentified very small

organisms still present in large numbers. Brown filamentous strands of flocs are present.

3 May 89 No ciliates are observed in aeration tank. Rotifers, round worms, and unknown very small organisms are present.

4 May 89 The number of rotifers has increased. Stalked ciliates are again observed. The unknown tiny organisms still continue to be abundant.

8 May 89 The number of mites has decreased greatly. There are now a lot more stalked ciliates and rotifers. No free-swimming ciliates are present now. The unknown organisms are still present in large numbers.

<div align="center">

Powder Activated Carbon/Activated Sludge
Microscopic Examination

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<u>8 November 89</u>

Tank 1 - The flocs in the aeration tank are golden brown with carbon particles in them. There are free-swimming ciliates, *Paramecium*, and many of the unknown motile organisms in the sample.

Tank 2 - The flocs in the aeration tank are brown with carbon particles incorporated within the flocs. There are many *Paramecium* and free-swimming ciliates present. A few rotifers were also observed. The unknown motile organisms are still numerous.

Tank 3 - The flocs are very dense and are the color brown. Many *Paramecium*, free-swimming ciliates, and unknown motile organisms are present in aeration tank. A few rotifers were also present.

Tank 4 - The flocs of tank 4 are brown and dense. There are many *Paramecium* and stalked and free-swimming ciliates present. The unknown motile organisms are still numerous.

Tank 5 - Many more rotifers in tank 5 than in any of the other tanks. Tank 5 has the same diversity of organisms (*Paramecium*, stalked and free-swimming ciliates, and unknown motile organisms) found in the other tanks.

14 November 89

Tank 1 - The aeration tank contains many *Paramecium*, free-swimming ciliates, and unknown motile organisms. A few round worms were also seen. Clear filamentous material is present throughout the sample. Carbon particles are found within the floc material.

Tank 2 - Tank 2 contains more filamentous material than does tank 1. There are also more carbon particles in the floc material. Organisms present are *Paramecium*, stalked and free-swimming ciliates, and the unknown motile organisms.

Tank 3 - The amount of filamentous material in tank 3 is the same as in tank 2; however, there are more carbon particles present in the floc material. *Paramecium*, stalked and free-swimming ciliates, and the unknown motile organisms are all present.

Tank 4 - There are many free-swimming ciliates present in tank 4. These ciliates are very active in the flocs. They move very quickly and scavage over the flocs. Stalked ciliates, *Paramecium*, and a few flat worms are present in the tank also. There are a lot of carbon particles in the floc material; consequently, the flocs are a very dark color.

Tank 5 - The abundance of organisms is much less in tank 5 than in tanks 1, 2, 3, and 4. Present in the aeration tank are *Paramecium*, stalked and free-swimming ciliates, and the unknown motile organisms. The flocs of tank 5 are not as large as in the other tanks, and are a golden brown color.

Tank 1 - There continues to be a number of the unknown motile organisms. Stalked and free-swimming ciliates and *Paramecium* are also present. No rotifers were seen in this tank.

Tank 2 - Many stalked ciliates are present in tank 2. There are a few *Paramecium* and round worms. The unknown motile organisms are still present in large numbers.

Tank 3 - There are many of the unknown motile organisms in tank 3. Free-swimming ciliates are also present in large numbers. *Paramecium*, stalked ciliates, and round worms were found in fewer numbers than the free-swimming ciliates.

Tank 4 - Carbon particles are found in the floc material. The unknown motile organisms are present in large numbers. Stalked and free-swimming ciliates are also found. No round worms or rotifers were present in tank 4.

Tank 5 - No *Paramecium* or stalked ciliates are present in tank 5. The unknown motile organisms are numerous, however. The flocs are a brown color.

21 December 89

Tank 1 - The flocs of tank 1 are golden brown with carbon particles within the flocs. Aeration tank contains *Paramecium*, stalked and free-swimming ciliates, and round worms. The unknown motile organisms are also present in large numbers.

Tank 2 - The flocs of tank 2 are large and darker in color than in tank 1. There are more carbon particles in the flocs of tank 2 than tank 1, also. There are more free-swimming ciliates than there are stalked ciliates in tank 2. The unknown motile organisms are still present in large numbers.

Tank 3 - The flocs of tank 3 are more threadlike than in tanks 1 or 2. Free-swimming ciliates are more abundant than stalked ciliates. The unknown motile organisms are present in tank 3, also.

Tank 4 - The flocs of tank 4 are threadlike with a lot of carbon particles within the floc material. There are many free-swimming ciliates, less stalked ciliates, *Paramecium*, and many of the unknown motile organisms.

Tank 5 - The few flocs present in tank 5 are a golden brown color. Many of the unknown motile organisms are present in tank 5. Also present are free-swimming ciliates and *Paramecium*.

<u>Activated Sludge Study,</u>
<u>Microscopic Examination</u>

<u>8 August 89</u>

2-day - Flocs in aeration tank are very small. There are many hundreds of the unknown, very small motile organisms. Also present are *Paramecium*, stalked and free-swimming ciliates.

4-day - Present in aeration tank are *Paramecium* and stalked ciliates. No free-swimming ciliates were observed. The unknown organisms are present in large numbers, also.

8-day - More *Paramecium* are present in this aeration tank than in the 2- or 4-day aeration tanks. The flocs are large and dark.

16-day - There is more diversity of organisms in this aeration tank. Present are *Paramecium*, stalked and free-swimming ciliates. The unknown organisms are present. The flocs are light brown and more dense than those in the other aeration tanks.

Control - Only organisms present are the unknown, very small motile organisms.

<u>10 August 89</u>

2-day - Flocs are small and a light brown color. Present in the aeration tank are *Paramecium*, stalked and free-swimming ciliates. Aeration tank also contains the unknown motile organisms.

G11

4-day - Few organisms are present in aeration tank. No *Paramecium* are present. There are a few stalked and free-swimming ciliates.

8-day - There are many *Paramecium* in aeration tank. Aeration tank also contains free-swimming ciliates, but no stalked ciliates were observed. The flocs are light brown and are fairly large.

16-day - Present in aeration tank are *Paramecium*, stalked and free-swimming ciliates. Many of the free-swimming ciliates are actively moving about, in and between the flocs. The unknown motile organisms are present, also. The flocs are light brown and fairly large.

Control - Many thousands of the unknown motile organisms are present.

18 August 89

2-day - Present in aeration tank are *Paramecium*, stalked and free-swimming ciliates, and the unknown motile organisms. There are few flocs present in sample.

4-day - Stalked and free-swimming ciliates and a few round worms are present. Also present are the unknown motile organisms. There are more flocs in the 4-day tank than there were in the 2-day aeration tank.

8-day - There are many *Paramecium* in the 8-day tank. Also present are stalked ciliates. There are few flocs in sample.

16-day - Many more stalked ciliates in 16-day tank. There are a few *Paramecium* and free-swimming ciliates present. The unknown motile organisms are also present.

29 August 89

2-day - The flocs are less dense than when previously observed. No stalked ciliates or *Paramecium* were present. There are free-swimming ciliates present, though. Also present are the unknown motile organisms.

G12

4-day - There are many *Paramecium* present in the 4-day aeration tank. Also present in less amounts are stalked and free-swimming ciliates. Unknown motile organisms were observed, too.

8-day - The number of *Paramecium* is less than the 4-day aeration tank. There are many free-swimming ciliates, but no stalked ciliates were observed. The flocs are large with many active free-swimming ciliates moving in and between flocs.

16-day - There are many free-swimming ciliates in the 16-day aeration tank. There are less, but still present, *Paramecium* and stalked ciliates, and the unknown motile organisms. The flocs are thick and fairly dense.

Control - A few *Paramecium* and one stalked ciliate were observed in sample. There were many free-swimming ciliates and the unknown motile organisms.

11 September 89

2-day - The flocs are generally small, but dense. The flocs have a very large number of organisms present in them. Organisms present are *Paramecium*, free-swimming ciliates, and the unknown motile organisms. No stalked ciliates were observed in the sample.

4-day - A few free-swimming ciliates are present, but not nearly as many as in the 2-day aeration tank. *Paramecium* and the unknown motile organisms are also present. No stalked ciliates were seen.

8-day - The flocs in the aeration tank are small, but dense. There are many free-swimming ciliates in the flocs; also present are *Paramecium*. No stalked ciliates were present.

16-day - The flocs in the aeration tank are small, but dense, as in the 8-day aeration tank. There is more diversity of organisms in the 16-day tank. Present are *Paramecium*, stalked and free-swimming ciliates, and the unknown motile organisms.